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PREFACE

The 47th Southern Pasture and Forage Crop Improvement Conference (SPFCIC) held at Mississippi State University upheld the standard of previous meetings that has resulted in this conference being considered by many as the premier work-shop - conference for forage/livestock professionals. The host organizing committee chaired by Dr. Werner Essig provided excellent meeting facilities and the various Work Group and General Session Program Chairs organized stimulating and thought provoking programs.

The four Work Groups associated with the SPFCIC (Forage Breeders, Forage Utilization, Forage Physiology and Ecology, and Forage Extension) represent a diversity of interests. This diversity is highlighted by the papers from these Groups which are published in these proceedings. Topics range from germplasm collection and evaluation to pasture nutrient cycling to economics of various forage systems. These papers highlight the central role that forages continue to serve in the agricultural production enterprise of the Southeastern United States. The SPFCIC general session program papers focus attention on ways that governmental decisions and regulations may markedly impact forage research and production. These proceedings also contain the minutes of the business meetings of the various Work Groups and the SPFCIC general session.

Special thanks are extended to the members of the SPFCIC Executive Committee for their assistance to the Chair throughout the year.

K. H. Quesenberry
Chairman, 47th SPFCIC

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ANIMAL WELFARE: BOTH SIDES OF THE ISSUE

John E. Harkness

Human beings, especially those in the more developed but less regimented societies, are faced continually with having to select among alternative actions. Those choices may be of value (good or bad), of responsibility (right or wrong), or of comparison (good or better), although those distinctions may be too finely drawn. The course of action taken given alternative choices is determined by a constellation of internal and external factors, such as (1) short and long term consequences of that action, 2) compatibility with religious, moral, and cultural mores, and (3) regulations or group consensus.

It should be obvious, given this spectrum of influences, that individuals or groups may vary considerably in which alternative is selected, which in turn may lead to the major crusades of the present era: abortion (or not); gun control (or not); civil rights (or not); animal use (or not); and prayers in school (or not).

Persons skilled in resolving conflict and in advising on right-wrong (moral decisions) consider that most persons' beliefs are based on prejudice, cultural background, peer pressure, parental views, and sloppy thinking - a moral fabric accepted uncritically. And they estimate at least 70% of the U.S. population will compromise convictions to avoid social isolation. So it is often difficult to determine what anyone really believes.

The aspect of philosophy that address making choices is ethics, and ethics is the establishment and use of specific criteria for making those judgements of value, responsibility, and comparison.

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If we ask various nationalities how they (choose to) use animals, we receive, as expected, a variety of answers: The Chinese may skin dogs and cats for coats or food while the British allow dogs but not children into some restaurants. A West African may swerve a car to kill a dog to appease a god of iron, while a Jain in India will kill no animal, even a blood-sucking mosquito. Obligations to animals are culturally conditioned. But all these societies, to one extent or another, share a common code that, generally, reveres life and condemns the unnecessary infliction of pain and suffering on at least some animals (and some people). In China that animal may be the water buffalo, in Nigeria the rabbit, and in the United States the dog.

The question of what to do or not to do with animals is not a worldwide debate, at least that affects American agriculture or research laboratories, but what Western Europeans and our fellow North Americans do and think affects us very much.

Many public opinion surveys have been taken in the United States to determine the pattern of conflict over our killing of approximately 6 billion animals yearly. Agriculture gets off easy. Even though 96.5% of all animals in the United States were killed for meat, only 0.14% of comments (in one survey) concerned slaughter for food. 2.6% were killed in hunting, and drew 0.40% of comments; 0.4% killed in pounds (albeit around 15 million dogs included) composed 2.61% of comments; but the 0.3% killed in research elicited a staggering 95.04% of comments. So the focus remains primarily on animals used in research, mostly biomedical research, in which farm animals constitute a small but growing component.

If Americans are asked if they support the reasonable use of animals in research (is it right or wrong to use animals) most surveys indicate 55 to 70% of people do approve of reasonable use with 25 to 40% disapproving. Elections in Colorado to ban fur sales, in Massachusetts to change animal husbandry practices, and elsewhere to curtail animal use have failed, although the well-funded and effectively administered animal welfare groups have, as a minority, accomplished far more politically than they have had influence on public opinion. Both state and national legislation has become highly restrictive, and no end to this trend is in sight.

Some surveys have been taken regarding public views of food animal agricultural practices. One survey indicated 61% believe farmers do not mistreat animals, which leaves 39% unsure or certain (19%) that they do. Four percent of slaughter house employees may be truly cruel. In Iowa 52% of farmers interviewed said castration causes large animals to suffer; 32% said dehorning causes pain; 78% said tail docking pigs is painful, but 61% said there is no pain from close confinement, as practiced with chickens, veal calves, or swine. In Europe, generally, traditional animal husbandry practices, as conducted in the United States, have minority support, and real concern exists that European Countries may, sometime, refuse importation of meat produced American style. Sweden is eliminating cage housing for poultry, and Scandavavia, Germany, Holland, and Switzerland are moving in many ways to reduce and eliminate high density housing. England may require anesthesia of animals before castration and dehorning. Ingrid Newkirk, a lader of the powerful animal rights lobby People for the Ethical Treatment of Animals (PETA), said, on the other hand: "See meat for what it really is, antibiotic and pesticide laden, nothing but parts of a tortured animal." The rest of the world just seems to watch and wonder about our concerns about animals, as they themselves are more concerned about the human misery that surrounds them.

What, then, are the big issues in animal agriculture that elicit, each year, a more furious debate and, inevitably, more restrictive legislation? Some issues are (1) close confinement of chickens, veal calves, and swine; (2) genetic selection for muscled, milk or egg producing mutants; (3) methods of slaughter and preparation for slaughter; (4) transportation; (5) diseases of confinement; (6) use of food grains to produce meat; (7) mutilation via debeaking, dehorning, castrating, branding, and implanting; (8) facilities with ammonia gas, slatted or concrete floors, and prolonged darkness; and (9) consequences for human health from our animal product diet. How do we (and others) decide what is "right and wrong," "good and bad," "better or best" regarding aspects of this list?

There is common ground. Both pro and con agriculture animal use advocates are against unwarranted cruelty, consider an animal's life as something special, and agree that concern for animal welfare is an economic as well as moral consideration. They may agree also that animals can think, even reason, remember, communicate, sense, and feel pain and distress. If both sides try hard they may agree that retarded humans, human infants, and at least some animals may have much in common. They may also agree that we humans, having removed certain animals from their natural environment, are now responsible for providing for some of the animal's needs, and that we are obligated by custom (and law) to care for animals dependent on us. Some of us may even go so far as to say that our obligations to care for confined, altered animals are "rights" conferred on or held by those animals. We are obligated to provide the essentials for life: freedom from pain and distress, food, water, and shelter. We who in overwhelming numbers are urban born and resident, who never farm or slaughter or breed animals, who see animals as individuals pets or as cellophane wrapped pieces rather than as herd or economic animals, easily see animals as deserving the same "life, liberty, and pursuit of happiness" we jealously guard for ourselves.

Generally, those usually good people who support animal use utilize a utilitarian ethic: what is good is so because the benefits outweigh the costs: We chose to use or not use animals depending on the consequences of that use. This is animal welfare as a science: modern U.S. animal husbandry has few costs (negative aspects) because there is no or little evidence of pain or suffering and little or no evidence of stress; there is absence of disease, good growth, high production, and reproductive success. These are the criteria of well-being. Intensive husbandry provides low-cost, high-quality food, which the public demands. Certainly there are aberrations, but overall the system works and in many ways humane care is obvious. And have not some of those European experiments in open range husbandry raised food costs considerably and have lead to increased, not reduced, disease problems? And will the "let sheep be sheep" naturalistic lure really sell lamb in this country? But underneath the cost-benefit analysis resides the firm foundation of a moral limit, a rigid code that prevents cruelty regardless of what potential good consequences might result from a cruel act. That rigid rule that overrides outcomes is the deontologic ethic, used prominently in the political arena and by those opposed to animal use.

Those who oppose animal use for food, pets, sport, or research are usually good people also. They, at their most convincing, do no more than what we do when we adhere strictly to our religious and cultural beliefs. We do not weigh arguments, outcomes, pros and cons - we say simply something is good - right or bad - wrong depending on whether or not the Bible, Koran, Bill of Rights, or Congress says it is. Therefore, if a non-violent individual states his or her conviction that animal life is special and that there are no moral differences between a human and a cow or a dog and a pig, should we not respect that conviction? Is that viewpoint of an animal's rights, that a deeply held conviction determines an action, less valid than for a Baptist or VFW member or Moslem standing on his or her inspired text or oath? Can we dismiss the criticisms of animal agriculture held by animal rights advocates as wrong and unrealistic? I do not think so, because that use of a moral standard is the deontologic ethic and it is certainly a valid approach to decision making. It is unfortunate that deontologists sometimes fall back to the utilitarian position and make truly unsubstantiated assesments of the costs and benefits of various types of animal use, because by doing so they expose themselves to factual contradiction. I do think we had better get together with our reasonable opponents and with ethicists to keep our debate constructive and make changes before the radical fringes of each group set the agenda for us.

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GRASS BREEDING RESEARCH AT TEMPLE, TEXAS

Bruce A. Young

INTRODUCTION

Grass breeding research at Temple, TX is conducted by the USDA-ARS at the Grassland, Soil and Water Research Laboratory. The laboratory is in the Blackland Prairie land resource area of central Texas and the Temple area has an average annual precipitation of 86.8 cm. Heavy clay soils predominate and the dominant native perennial grasses include little bluestem, indiangrass, big bluestem, sideoats grama and switchgrass.

Research is focused on warm-season perennial grasses, and agronomic problems associated with both introduced and North American species are under investigation. The grass research team is comprised of the following four scientists and their respective specializations: Byron Burson, grass cytogenetics; Charles Tischler, plant physiology; Paul Voigt, grass breeding; and Bruce Young, grass breeding.

The following will be a broad overview of the grass research conducted at Temple. A selected bibliography is included for those who are interested in either more information or specific details of the research.

Grass breeding research at Temple can be divided into five major areas. These are 1) apomixis, 2) forage quality, 3) phylogenetics, 4) establishment, and 5) stress tolerance.

APOMIXIS

For many years Voigt and Burson have conducted various research projects with species that reproduce wholly, or in part, by apomixis (asexual seed production). Because apomictic grasses are intractable to breeding using methodology appropriate for sexually reproducing species, research has involved understanding the mechanisms of apomixis in three genera, _Paspalum_, _Eragrostis_, and _Tripsacum_, and then devising breeding procedures that can be used to improve three species within the respective genera, common dallisgrass, weeping lovegrass, and eastern gamagrass.

The specific method of apomictic reproduction and the inheritance of apomixis are studied in these species and in related species that can be used for hybridization to produce new genetic combinations. Other factors that affect the manipulation of apomixis and hybridization are also studied. These include chromosome number, meiotic behavior, method of pollination, and hybridization barriers. Hybrids can be either apomictic, sexually reproducing, or a combination of both (facultative apomixis). Hybrid genotypes that have desirable agronomic characters and reproduce by apomixis are candidates for 'instant' cultivars because they are true-breeding.

Research by Burson and Voigt has determined the particular type of apomixis (diplospory) present in eastern gamagrass, _Tripsacum dactyloides_. They have also found that mode of reproduction is related to ploidy level. Polyploids are apomictic, but diploids are sexual. The transfer of apomixis from the polyploid to the diploid level, and the transfer of sexuality from the diploid to the tetraploid level is receiving considerable research attention. With the goal of transferring apomixis to corn, Voigt and Burson have initiated a project to hybridize eastern gamagrass and _Zea mays_.

FORAGE QUALITY

Weeping lovegrass, _Eragrostis curvula_, is a facultatively apomictic species, which although a valuable forage grass, is noted for its poor quality under low input management. Voigt has devised a breeding scheme for the systematic improvement of forage quality in weeping lovegrass that takes advantage of the range of reproductive types produced upon inter- and intraspecific hybridization. Plants that reproduce sexually are crossed with high quality apomictic plants. Among the hybrids produced, the desirable higher quality apomicts are ready immediately for testing as potential cultivars and the sexual hybrids can be crossed with either their apomictic sibs or with additional apomictic accessions to produce more apomictic hybrids. This can be repeated to generate additional genetic combinations, of which the agronomically superior apomictic genotypes can be tested for their potential as new cultivars. NIR spectroscopy is being used to analyze plants for various components of forage quality.

PHYLOGENETICS

The phylogenetics of _Paspalum dilatatum_ has been a focus of Burson's research with the genus _Paspalum_. Common dallisgrass is an obligately apomictic pentaploid with a chromosome complement comprised of three different genomes. The goal of this research has been to use phylogenetic analysis to determine the three _Paspalum_ species that recombined in nature to create what is known as common dallisgrass. With this knowledge the species could be resynthesized to produce many new 'common dallisgrass' types, some of which may have superior agronomic characteristics. Burson has determined the source of two of the three genomes (_Paspalum intermedium_ and _P. jurgensii_) that make up the chromosome complement of common dallisgrass and has identified a hexaploid biotype from Uruguay as the probable candidate for the source of the third genome.

ESTABLISHMENT

Research to improve grasses for semi-arid environments is an important part of the USDA-ARS program at Temple. Problems with seedling establishment are common among many desirable grasses that are adapted for areas with long periods of drought. This includes both native species as well as introduced species such as kleingrass, _Panicum coloratum_.

The role post-harvest seed dormancy plays in establishment is being investigated by Tischler, Young, Burson, and Voigt. Seed treatments that alleviate dormancy have been identified and populations of kleingrass and Wilman lovegrass, _Eragrostis superba_, with reduced seed dormancy have been developed through recurrent selection. The selected populations will be used to determine the effect of dormancy on reseeding and stand maintenance in these two species. Seed treatments that improve the germination of dallisgrass also have been identified.

Because kleingrass seedlings grow slowly and often fail to establish in a rapidly drying soil profile, recurrent selection has been used by Young and Tischler to develop populations of kleingrass with an increased seedling growth rate. Also, to improve seed yield and seed quality in kleingrass, Young has used recurrent selection to develop populations with resistance to seed shattering.

In most warm-season grasses the subcoleoptile internode elongates to push the coleoptile to the surface after germination of the seed. Some grasses (eg. kleingrass and blue grama, _Bouteloua gracilis_) often elongate this internode more than necessary which can result in the crown node of the plant being elevated above the soil surface. This contributes to poor establishment by impeding the development of the permanent root system that initiates from the crown. Tischler is investigating the control of subcoleoptile internode elongation and whether the rate of elongation can be genetically altered to produce genotypes that will not elevate crowns. Young and Tischler are comparing early adventitious root formation and growth between those warm-season grass species that establish quickly and those that are considered poor establishers. The extent of genetic variation for early root development is also being investigated.

Young has recently initiated a genetic improvement program with big bluestem, _Andropogon gerardii_ and switchgrass, _Panicum virgatum._ An initial collection has been assembled to be evaluated for adaptation and to assess long term improvement needs. We anticipate that problems with establishment will be the subject of initial research projects.

STRESS TOLERANCE

Several aspects of stress tolerance are being explored. Tischler, Voigt, and Burson are investigating the relationship between leaf epicuticular wax content and water loss in _Eragrostis sp_. and _Paspalum sp_. In the same genera, they are comparing heat tolerance _per se_ with a solute leakage test that has been proposed as a rapid screening tool for heat tolerance. Tischler, Voigt and Young have screened germplasm of weeping lovegrass and kleingrass for seedling drought tolerance by growing plants in nondraining containers and then withholding water to an empirically-derived endpoint before rewatering and assessing recovery. A population of kleingrass with enhanced seedling drought tolerance has been developed through recurrent selection using this screening system.

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EXPLORATION FOR TRIFOLIUM GERMPLASM IN BULGARIA IN JULY 1990

K. H. Quesenberry
G. R. Smith

This paper summarizes a germplasm exploration and collection trip conducted in Bulgaria 14 - 27 July, 1990. The purpose of trip was to collect seeds of species of the genus *Trifolium* with special emphasis on the species *T. vesiculosum*, and *T. hirtum*, but including the range of annual and perennial species encountered in various habitats. The participants in the exploration and collections were:

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Jana Guteva, *Trifolium*, *Medicago*, and *Lotus* Specialist, IIPGR, Bulgaria
Siyka Angelova, *Vicia* and *Lupinus* Specialist, IIPGR, Bulgaria
Dotcha Chamov, Perennial Grasses Specialist, IIPGR, Bulgaria
Dimiter Delipavlov, Professor of Botany, Plovdiv University, Bulgaria

The Clover and Special Purpose Legume Crop Advisory Committee (CSPL/CAC) in a report to the National Plant Germplasm System had established that the area of southeastern Europe (Yugoslavia, Romania, Bulgaria, and Albania) was a priority for germplasm collection and that the species *T. vesiculosum*, and *T. hirtum* were priority species. In the summer of 1989 Dr. George White (USDA/ARS/PIO) visited the Institute of Introduction and Plant Genetic Resources (IIPGR), Sadovo, Bulgaria and learned of plans by IIPGR to collect forage legume germplasm in 1989-91. Dr. Dimitar Stoyanov, Director IIPGR, indicated to Dr. White that U.S. cooperators would be welcome on the expedition planned for 1990. Dr. White then contacted Dr. R. R. Smith (USDA/ARS/USDFRC), chairman of the CSPL/CAC, who contacted Drs. Quesenberry and Smith to develop the collection proposal. A proposal was submitted to the S-9 Regional Technical Committee in late September 1989, and although it was too late for the normal evaluation cycle for 1990, it was approved for funding in February, 1990. International travel and per diem for Quesenberry and Smith was funded through the proposal with in-country travel, lodging and meals paid by IIPGR. A reciprocal agreement provided for two Bulgarian germplasm specialists to visit the U.S. in Spring 1991 with similar funding arrangements; however, economic conditions in Bulgaria have delayed this reciprocal visit.

The U.S. team members arrived 15 July and began the exploration with a visit to IIPGR on 16 July. The Institute has very good facilities for germplasm storage and excellent herbarium specimens of a number of *Trifolium* spp. These specimens were reviewed and plans for the trip were finalized. Since our primary interest was annual *Trifolium* species the area to be collected was in the southeastern part of Bulgaria. Table 1 is a listing of the towns and villages and the general collection route.

The collection expedition traveled almost 2000 km and made 150 collections. A number of the collections were mature and sometimes deteriorated, thus their taxonomic identity could not be determined. The IIPGR had set the dates for collection based on a previous trip through part of this region in 1989. Their dates were planned so that the annual species would just be maturing. As we traveled it became apparent that the season in 1990 was earlier than 1989 and that most annual species were completely mature and dried. Nevertheless, the dry climate had preserved the plants well and collections and identification were

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possible at most sites. An additional advantage of the earlier season in 1991 was that most perennial species we encountered had some mature heads and we were able to make collections of perennials as well. Our original correspondence has suggested that we desired to concentrate on *T. vesiculosum*, *T. hirtum*, and other annual species. The area where we collected was abundant with annual *Trifolium* species and our itinerary allowed us to accomplish the goals of this trip.

However, on the final day of collection into the more mountainous area southwest of Plovdiv we encountered several perennial species not previously seen which suggests that additional collections in this area would be productive. It is quite possible that some of the perennial *Trifolium* spp. described by Zohary and Heller but unavailable in any germplasm collections my be native to western Bulgaria. The Flora of Bulgaria lists one such species (*T. pignantii*).

Table 2 is a tentative listing of the *Trifolium* species colected. This list includes identifications made on material grown in the greenhouse in Florida in Spring 1991. Some species have not yet flowered, and others are still pending identification. Taxonomic classification of some of the small annual species (particularily the hop clover types) is difficult. At present we have a potential of 43 different species in the collection (29 with reasonably confident identification, 14 other single or multiple ascession groups most of which appear to be different based on foliage type. Assuming that some of these 14 presently unidentified collections will be determined as the same as another collection which was given a name, it would still appear that about 40 different species were collected. "The Genus Trifolium" (Zohary and Heller, 1984) suggests that between 40 and 55 species had been documented from Bulgaria. Professor Delipavlov indicated that the "Flora of Bulgaria" listed about 52 species. Thus, it appears that this collection represents a major portion of the annual and perennial *Trifolium* species found in Bulgaria.

Table 3 is a listing of other legumes collected. In the mountainous areas we encountered occasional plants of *Coronilla*, *Lotus*, *Melilotus*, and *Onobrychis*, whereas in the lower and drier areas we only saw annual *Medicago*, and *Cytisus*. In the area near the Black Sea, it appeared that a number of annual *Medicago* species had been present earlier in the season, but most plants had deteriorated and only scatted pods were present.

Small samples of all collections are being grown at the University of Florida (Quesenberry) and the *T. vesiculosum* and *T. hirtum* samples are being grown by at Overton, Texas (G.R. Smith). Herbarium voucher specimens will be prepared of all collectionswhich flower. Original and/or increased seed of all samples will be deposited with the appropriate Plant Introduction Station once taxonomic identity is verified.

The U.S. team members feel that this expedition was most successful and that germplasm collected has potential to be of importance to U.S. agriculture. Of particular interest are the 15 collections of *T. vesiculosum* (only eight collections presently in the U.S. germplasm system) and 12 collections of *T. hirtum*. Additionally, several of the perennial and annual species collected are currently represented by fewer than 10 collections in the U.S. system (and often worldwide). One or more of the unidentified perennial species may currently not be represented in the U.S. collection.

The U.S. team members were impressed with the diversity and abundance and *Trifolium* species present in varied topographic habitats. This collection will aid in recording and preserving

this valuable germplasm. A concern exists that change in agricultural practices could lead to the loss of germplasm in some of these areas. The IIPGR is interested in continual cooperative collections efforts and such contact should be maintained.

Table 1. Program of the Expedition for Collecting *Trifolium, Medicago*, and other forage legumes.

15 July (Sunday) - Arrival in Plovdiv; Hotel - Plovdiv

16 July (Monday) - Plovdiv - Sadovo, Institute of Introduction and Plant Genetic Resources, Visit to the Herbarium, Collection near Asenovgrad

17 July (Tuesday) - Plovdiv, Pervomay, Byalareka, Gorskiisvor, Haskovo, Beliplast, Kardjali; Hotel Kardjali

18 July (Wednesday) - Kardjali, Momtchilgrad, Krumovgrad, Ivaylovgrad; Hotel Ivaylovgrad

19 July (Thursday) - Ivaylovgrad Kamilski dol, Debovetc, Malko Gradichte, Lubimec Svilengrad; Hotel Svilengrad

20 July (Friday) - Svilengrad, Levka, Drietchevo, Hlebovo, Topolovgrad; Hotel Topolovgrad

21 July (Saturday) - Topolovgrad, Kniajevo, Elhovo, Boliarovo, Goliamo, Kruchevo, Grudovo; Hotel Grudovo

22 July (Sunday) - Grudovo, Zvezdec, Malko Turnovo; Hotel Malko Turnovo

23 July (Monday) - Malko Turnovo, Gramaticovo, Mitchurin, Primorsko, Sozopol, Burgas; Hotel Burgas

24 July (Tuesday) - Burgas, Sunny Beach, Plovdiv; Hotel Plovdiv

25 July (Wednesday) - Plovdiv, Batak, Mountain resort, Plovdiv; Hotel Plovdiv

26 July (Thursday) - Plovdiv, Sofia, Frankfurt; Hotel Frankfurt

Table 2. Summary of *Trifolium* species collected in Bulgaria, July 1990 by K. H. Quesenberry and G. R. Smith.

Species Name	Number of Collections
T. alpestre	9
T. arvense	2
T. angustifolium	3
T. cherleri	4
T. campestre	2
T. constantinopolitanum	1
T. diffusum	8
T. echinatum	4
T. fragiferum	6
T. glomeratum	2
T. grandiflorum	1
T. heldreichianum	6
T. hirtum	11
T. hybridum	8
T. leucanthum	2
T. medium	1
T. michelianum	3
T. montanum	1
T. nigrescens	4
T. ochroleucum	11
T. pallidum	2
T. patens	2
T. pratense	5
T. purpureum	4
T. repens	6
T. resupinatum	1
T. scabrum	3
T. strictum	3
T. subterraneum	1
T. vesiculosum	15
T. spp (group 1 = 90-12,22,26)	3
T. spp (group 5 = 90-64,82,92)	3
T. spp (group 7 = 90-27,31)	2
T. spp (90-9)	1
T. spp (90-40a)	1
T. spp (90-45)	1
T. spp (90-47)	1
T. spp (90-50)	1
T. spp (90-52b)	1
T. spp (90-57)	1
T. spp (90-85)	1
T. spp (90-128)	1
T. spp (90-139)	1
T. spp (90-141)	1

Table 3. Other legumes collected in Bulgaria, July 1990 by K. H. Quesenberry and G. R. Smith.

Species Name	Number of Collections
Onobrychis spp	2
Lotus corniculatus	2
Coronilla varia	1
Melilotus alba	1
Cytisus spp	1
Medicago orbicularis	2

MACRONUTRIENT CYCLING AND UTILIZATION IN SUSTAINABLE PASTURE SYSTEMS

S. R. Wilkinson and J. A. Stuedemann

INTRODUCTION

The purpose of this presentation is to describe the effect of the grazing animal and its management on NPK cycling, and to relate the importance of mineral cycling to sustainable pasture systems. Major emphasis will be on nitrogen cycling.

Pasture Ecosystem Sustainability

Grazed lands make up approximately 48% of the total land area of the Southeast USA. Their sustainability from economic and environmental quality points of view are legitimate concerns of pasture and range scientists, natural resource scientists, livestock producers, and the general public.

The American Society of Agronomy has defined sustainable agriculture as a system "that, over the long-term, enhances environmental quality and the resource base on which agriculture depends; provides for basic human food and fiber needs; is economically viable; and enhances the quality of life for farmers and society." (Stewart et al. 1991). Sustainable systems maintain or enhance productivity while not polluting, degrading, exploiting the environment, or disrupting essential processes in the system. Sustainable pasture ecosystems are therefore those that maintain or enhance grazing animal productivity while using non-renewable and renewable resources wisely. Levels of external inputs to establish and/or maintain a given level of productivity and stability in agroecosystems are very much climate and site dependent. Ease of sustainability is a function of temperature and amount and distribution of rainfall (Savory 1988, Stewart et al. 1991). After temperature, solar radiation and water, N nutrition is the most limiting factor in pasture productivity. Sustainable pasture systems require N (and other mineral elements) in reasonably well-defined concentrations. Pasture productivity is controlled by soil fertility and by defoliation frequency and intensity with the grazing animal (Lazenby 1988).

In the real world, everything is connected to everything else, everything must go somewhere, and there is no such thing as a free lunch - not even with the help of the most sophisticated chemical and biological technology. Therefore, understanding succession, energy flow, water cycles and nutrient cycles are processes which help us comprehend, develop and control pasture productivity and demonstrate interdependence of various components of the ecosystem.

Nutrient Cycles

Nutrient cycles describe major pools, inputs, outputs and transformations. Pool sizes, flows between pools, areas of systems, and time scales are all variable, and "in toto" describe nutrient use and movement within specific ecosystems. Nutrient balances are used in connection with nutrient cycles to describe amounts and distribution of nutrients. Nutrient balances are obtained when nutrient inputs - nutrient outputs ± changes in ecosystem nutrients are equal to zero. They are a statement of the conservation of nutrient mass within the ecosystem. Nitrogen balances are useful for evaluating N availabilities for production of biomass, for determining efficiency of N utilization in producing products of economic value within the system, and for estimating the losses of N to the atmosphere (air quality), or N to drainage water (water quality). Nitrogen is neither created or destroyed, but may be added, lost, transformed, transported or re-used

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(cycled). Figure 1, modified from Wilkinson and Lowry 1973, is a schematic illustration of a nutrient cycle which forms a basis for developing annual N budgets.

Controls over mineral cycling can be classified into five categories: soil selection, soil management, crop selection and management, fertilization, and grazing animal management. While not the primary subject of this discussion, it should be understood that the establishment and maintenance of the soil organic matter pool is the basis of soil productivity in all agroecosystems. Soil N differences between grazed systems and machine-harvested systems occur as a result of degree of herbage utilization, return of residues, and turnover of N in these residues. Productivity of pastures is affected by managing the grazing animal (amount and intensity of defoliation) and by manipulation of the N cycle through N fertilization, biological N fixation, or return of N in residues. Goulding (1990) pointed out that in the United Kingdom, N gains from the atmosphere by direct absorption may be very high, and perhaps greater than from wet deposition. Losses of excess N to the air and water are also considered detrimental to environmental quality.

Deficiencies of P and K as well as other essential plant nutrients also reduce pasture productivity. However, better soil and plant diagnostic techniques and procedures for detecting and correcting P&K deficiencies exist than for N or S deficiencies. Sulfur depositions from the atmosphere are sufficient except for a few limited areas of low deposition, or high crop S removal. Sulfate retention is considerably greater than NO_3 retention in many soils.

ANIMAL MANAGEMENT

Livestock effects are brought about through differences in animal type, grazing behavior, plant species and part selectivity, distribution of excreta in time and space, stocking rates and grazing systems.

Animal type, behavior and distribution of Excreta

Animal species, age, size and sex affect herbage intake, nutrient intake, nutrient retention and ability to graze close and selectively. Animal mobility and behavior complicates the return of nutrients in animal residue whereas return of nutrients in plant residues is in place. Sheep tend to be more gregarious than cattle, and enhance localization of excretal nutrient returns. Sheep may utilize more of the forage grown.

Animals on range utilize forage to a higher degree near watering points (Arnold and Dudzinski 1978). Greater density of dung in areas near watering and shade points is frequently observed. (Wilkinson et al. 1989, Peterson et al. 1956a, Senft 1985). Wilkinson et al. 1989 found annual transport of K to watering points equivalent to 59% of the fertilizer K applied when steers were grazing endophyte infected tall fescue. Similar trends in NO_3-N in soil profiles were also observed. West et al. 1989 documented large accumulations of extractable P and exchangeable K near watering points. Dung return and urine return were similar spatially, suggesting that an evaluation of dung return might serve as an approximation for total excretal returns. (Sugimoto et al. 1987).

Even without transfer to unproductive areas such as woods, shade, watering points, fence lines, cow paths, the consumption and excretion of forage N by ruminants results in gathering of N from large areas of the pasture, and return to smaller areas. This concentrating effect may result in N application rates in urine of 200-1000 kg N/ha. Nutrients are frequently returned in too high a concentration to be used efficiently.

Additionally, on an annual basis, less than 35% of the pasture receives excretal N, some of which receives more than one application/year (overlapping of excreta). This uneven distribution

means some of the pasture will be under fertilized (depletion), and some over fertilized (accumulation). The effect of this uneven spatial distribution of excreta on pasture productivity is analogous to the effect of uneven fertilizer distribution on yields. The factors affecting fertilizer use efficiency with uneven fertilizer distribution are adequately described in Welch et al. 1964. Uneven distribution also occurs with rotational grazing, but the magnitude of the losses to unproductive areas may be smaller (Hilder 1966). Set-stocked animals may transfer more fertility to stock camps than rotationally grazed animals (Quin 1982).

Partitioning of ingested forage NPK to animal products

Nitrogen balances within animals are determined by measuring N intake in the forage eaten minus that retained in products (milk, liveweight gain, wool), and excreted in dung and urine. Nitrogen retention is greatest in actively growing livestock, and least in mature livestock. A general rule of thumb for removal of N in livestock products from a grazed pasture is 27.2 g N/kg liveweight gain (LWG), and 0.6 g N/kg milk produced. Phosphorus and K contents of LWG gain are 6.8 g P/kg and 1.5 g K/kg, and 1.0 g P/kg milk and 1.2 g K/kg milk. Nitrogen retention estimates as a percentage of dietary intake range from approximately 8% for LWG to 20% for high milk-producing cows. Such estimates are only approximate because the level of dietary N, age and type of animal, etc., also impact nitrogen retention.

A 250 kg steer ingesting 6 kg forage containing 3% N/day and gaining 0.8 kg per day may ingest 180 g N/day, retain about 22 g in LWG (12% retention) and excrete the remainder, 150 g N/day. Nitrogen excretion is in both urine and feces. The proportion of total N excreted in urine increases linearly with increasing N consumption. The relationship appears similar for legume or grass N. Jarvis et al. 1989 found that excretion of N between urine and feces was similar for grass/clover (N conc, = 2.47), and grass fertilized with 210 kg N/ha (N conc. = 2.40) at 55-60% of total N excreted in urine, but when fed grass fertilized with 420 kg N/ha (N conc. = 3.59%) about 74% of the total N was excreted in the urine. Nitrogen excreted in urine is water soluble, and immediately available for plant uptake and growth, as is K either from feces, or urine.

Dietary protein requirements for beef cattle are about 12%, or 1.92% N. Nitrogen concentrations associated with high growth rates of grasses and legumes are usually higher than this.

Phosphorus is excreted mainly in feces with the proportion of total P excreted as organic P being relatively constant over the range of 0.1 to 0.4% P in the diet, while the proportion of inorganic P increases. Therefore, the higher the P concentration of the diet, the greater the concentration of inorganic P in the feces, and the higher its availability for plant growth. Potassium excretion is mainly in the urine (50-90%). Sulphur excretion patterns in relation to S concentrations of forage eaten are similar to those of N. For sulphur, about 0.11 g S per 100 g of feed eaten appears in feces, while for N about 0.8 g N/100 g of feed eaten appears in feces.

Grazing System and Stocking Rate

Grazing system and stocking rate are the principal animal management choices for controlling pasture productivity. Stocking rate is the number or mass of animals per unit area. Grazing systems manage animals to utilize the forage. Whether N recycles more effectively under rotational or continuous grazing depends largely on the proportion of herbage grown consumed by grazing, and the uniformity of N return through excreta. Steele and Brock (1984) reported that rotational grazing to 1500 kg residual dry matter/ha resulted in more variable soil N than set stocking

grazing to a residual dry matter of 2900 kg DM/ha (rotational grazing = ± 200 kg N/ha while set stocking was ± 50 kg N/ha/yr).

Roquette et al. (1973) reported large increases in recovery and recycling of NPK with increased stocking rate in a grazing study with Coastal bermudagrass. Blue and Gammon (1963) also observed very high recoveries of K in grazed versus harvested plots. Peterson et al. 1956b reported that nutrient recycling is more effective at higher stocking rates than at low stocking rates. Their research indicates that recycling effectiveness is determined by excretal density and loss rates of nutrient contained in the excreta.

Hoglund (1985) demonstrated in paddocks severely grazed by sheep that loss of soil N occurred when less than 830 kg residual live dry matter (D.M.)/ha after grazing was maintained. The change in total soil carbon and nitrogen was linear over the mean residual live D.M. from 500 kg D.M./ha to 1200 kg DM/ha. Sheep grazing pastures to less than 1200 kg live D.M./ha led to increased variability of soil organic N and to losses of soil N as the amounts of residual live herbage decreased.

Mott (1973) described studies indicating that considerable retention of N occurred in guineagrass systems after N fertilization ceased. He calculated that after 8 years, there was still a 5% response over the unfertilized control. Because of the small amounts of N removed in LWG, and the large amounts of N excreted, the N fertilizer requirements of grazed pastures should be substantially less than for harvested forage. Three thousand kg of herbage containing 2.5% N when harvested removes 75 kg N, but if consumed by grazing may produce 300 kg LWG , containing about 8 kg N, with the remainder (67 kg N) excreted. Therefore, in the N balance of the grazed system, with no other losses other than animal products, very little N input would be required to maintain a balance. However, losses due to volatilization (ammonia volatilization and denitrification) occur, as well as losses due to leaching and run-off. Run-off losses are generally low because of low run-off volumes. However, severe grazing can enhance large surface run-off losses (Alderfer and Robinson, 1944). Other losses also occur as a result of transfer of excreta to unproductive areas (previously discussed) and as losses associated with the return of N in higher concentration, and amount than can be utilized efficiently by plants. These corresponding high rates result in higher probabilities of losses by leaching when cool, and wet conditions prevail, by denitrification when warm and wet conditions prevail, or by ammonia volatilization when warm and dry conditions prevail. The reader is referred to Gandar (1982), Jarvis et al. (1989), Ryden (1985), Ryden et al. (1984), and Ball and Ryden (1984) for a comprehensive discussion of these losses.

Ingestion and metabolism of forage N by livestock separates carbon from N (in urine), and increases its mobility, and opportunities for losses. Agronomic studies directed toward N recoveries from urine generally report maximum N recoveries in the range of 30-40% (Thomas et al. 1988). Ball and Keeney (1982), Williams et al. (1990), illustrate that preferential flow of urine through soil macropores reduces nutrient availability in pasture soils. Mclay et al. (1991) also point out that preferential flow through soil macropores can markedly increased leaching of fertilizer or animal urine. More rapid leaching may occur if rainfall or irrigation follows soon after fertilizer or urine application because solutes move rapidly through macropores before equilibration can occur with the bulk of the soil. After equilibration, macropore flow may bypass nutrients in micropores.

In the long-term N from feces may be more recoverable, or recycle more efficiently because of lower losses due to volatilization, and to leaching. Nitrification of the N in feces is required before it can be leached.

The following is a series of summary statements about the role of the grazing animal in nutrient cycling. They are based on many papers reviewed, and the model of N flows in pasture systems developed by Thornley and Verbene (1989).

1. Dry matter intake by ruminants reaches a maximum at a leaf area index less than maximum for photosynthesis.

2. Plant senescence losses decrease because frequency and/or severity of defoliation is increased with increased stocking density.

3. The proportion of total plant C and N recycled within the plant, and by litter to the soil decreases, while C and N recycled through animal excreta increases as stocking density increases.

4. Animal consumption, digestion, and metabolism separates C from N, and generally increases N availability for plant uptake, as well as availability for leaching, NH_3 volatilization, and denitrification losses.

5. Plant C and N recycled through animal excreta has greater opportunity for losses due to transfer to unproductive areas, non-uniform distribution, leaching, including preferential flow through soil macropores, volatilization as well as lowered N use efficiency associated with very high rate of return.

6. Soil organic matter may decrease if residual live plant dry matter yield left after grazing is less than 1200 kg dry matter/ha. Losses in soil organic matter also mean losses in the soil organic N pool which replenishes soil mineral N pools which supply mineral N for plant uptake and metabolism.

7. Pasture soil productivity is dependent on the size of soil organic N pools. Severe grazing, coupled with non-uniform return of excretal C and N can deplete this pool, and reduce soil and pasture productivity. There is a minimum size of the soil organic N pool below which soils are not productive, and a maximum size of soil organic N pool above which excessive leakage of mobile mineral N occurs. This may be defined as a climax soil organic N content (Middleton and Smith 1978).

8. N losses associated with poor excretal distribution increase as the proportion of N recycled by the plant decreases, and that recycled by the animal increases. Losses associated with excretal return are often greater from urine than fecal returns in the long-term.

9. Severe grazing, can result in depletion of C and N pools in the soil ultimately reducing pasture productivity, and perhaps result in unacceptable losses of N to the environment, either in drainage water or volatilization.

10. Distribution of feces and urine in space may be similar based on work of Sugimoto et al., 1987. If this can be confirmed it will help by physically defining nutrient return patterns.

RESEARCH NEEDS

Macronutrient cycling research goals are to provide management practices to achieve maximum effectiveness of nutrient inputs and minimum macronutrient losses from the pasture ecosystem. Some specific research needs are the following:

1. Better chemical and/or biological tests for total available N and P and rate of release of N and P from soil organic matter pools, and from plant and animal residues (excreta).

2. More precise determination of the fate of N in grazed ecosystems accompanied by long-term research on the effect of animal management (stocking rate and grazing system) on N transfer to air and water drainage from plant and animal residues, and N use efficiency in plant growth from plant and animal residues.

3. Improved grass/legume pasture systems which are persistent and productive in southern temperate and subtropical environments.

4. Wide-spread application of conservation of mass theory, and balanced fertilization research to include amounts as well as proportions of fertilizer nutrients added to all agroecosystems. This is needed to document pasture ecosystem sustainability and environmental acceptability.

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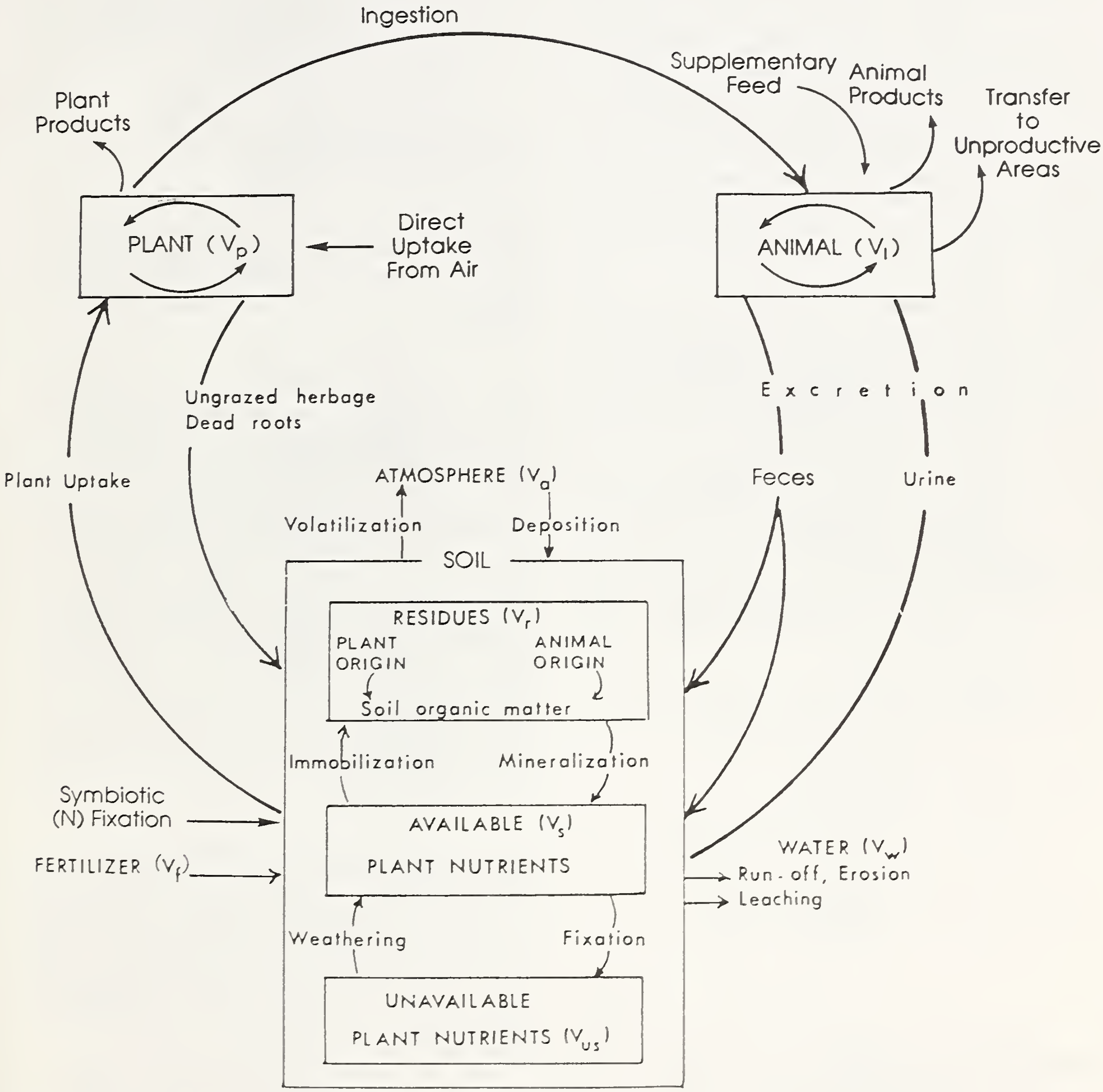

Figure 1. Mineral nutrient cycle for pasture ecosystems.

PRACTICAL MODELS FOR DESCRIBING FORAGE GROWTH AND NUTRIENT UPTAKE

Allen R. Overman[1]

INTRODUCTION

The invitation to address this subject offers both an opportunity and a challenge; an opportunity to summarize the long series of articles written over the past seven years and a challenge to reduce the mathematics to practical terms. A letter on 13 November 1857 from Michael Faraday (experimentalist) to James Clerk Maxwell (theoretician) says it so nicely (MacDonald, 1964):

> *There is one thing I would be glad to ask you. When a mathematician engaged in investigating physical actions and results has arrived at his conclusions may they not be expressed in common language as fully, clearly, and definitely as in mathematical formulae? If so, would it not be a great boon to such as I to express them so?--translating them out of their hieroglyphics, that we also might work upon them by experiment. I think it must be so, because I have always found that you could convey to me a perfectly clear idea of your conclusions, which, though they may give me no full understanding of the steps of your process, give me the results neither above nor below the truth, and so clear in character that I can think and work from them. If this be possible, would it not be a good thing if mathematicians, working on these subjects, were to give us the results in this popular, useful, working state, as well as in that which is their own and proper to them?*

Maxwell was pleased to oblige, since Faraday's work had been the guiding light for the development of the theory (model). Let us try to follow that tradition.

Models can be divided into two groups, viz. geometrical and functional. Geometrical models are used to represent physical form (stalks, leaves, fruit, etc.), while functional models are used to describe relationships among variables and parameters. Our focus is on the latter of these. Within this group, we have divided the models into (1) empirical and (2) phenomenological. Both models are dynamic, i.e. contain time explicitly. The former is simpler mathematically, while the latter is more comprehensive. Following discussion of each, procedures for estimation of forage nutrient concentration (N, P, K) are described.

Input factors include applied nutrients, harvest interval, and water availability. Output factors include dry matter production and forage nutrient concentrations. Our discussion will focus on bermudagrass, since a large database exists from forty years of research. The analysis applies to fixed harvest interval.

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Empirical Model

This model was developed by examining experimental data (Overman et al., 1988a, b) from several field studies. It is given by

$$Y_n = \frac{Y_T}{2}\left[1 + erf\left(\frac{t_n - \bar{t}}{\sqrt{2}\sigma}\right)\right] \qquad [1]$$

where

Y_n = cumulative dry matter through n th harvest, t/ha

$= \sum_{i=1}^{n} \Delta Y_i$

ΔY_i = dry matter for i th harvest, t/ha

Y_T = total dry matter for season, t/ha

t_n = time to n th harvest (since Jan. 1), wk

$\bar{t}$ = time to mean of dry matter distribution, wk

σ = standard deviation of dry matter distribution, wk

erf = error function

Equation (1) contains three parameters, viz. $\bar{t}$, σ, and Y_T. These are evaluated from data by either graphical or regression methods (Overman et al., 1988a). Rate of accumulation, dy/dt, is given by

$$\frac{dY}{dt} = \frac{Y_T}{\sqrt{2\pi}\,\sigma}\exp\left[-\left(\frac{t-\bar{t}}{\sqrt{2}\sigma}\right)^2\right] \qquad [2]$$

Response of the model is shown in Figure 1, where typical values of the parameters are assumed. Cumulative yield (Y_n) is shown in Figure 1(a), while growth rate (dy/dt) is shown in Figure 1(b). By this model, growth rate follows a normal (bell-shaped) distribution over the season. The standard procedure for testing this assumption is to plot the data in normalized form (Y_n/Y_T) on probability paper. If the assumption is correct, then Y_n/Y_T vs t yields a straight line, with mean and standard deviation of $\bar{t}$ and σ, respectively. Figure 2 shows a plot of Equation (1) in this form for typical $\bar{t}$ and σ. Overman et al. (1988b) found that, to good approximation, the assumption is correct.

This model was developed by observing patterns in data and then identifying an appropriate function to describe it. The model, Equation (1), is relatively easy to use on a pocket calculator once the coefficients are evaluated.

The next step is to relate model parameters to applied N, harvest interval, and water availability. Submodels are used for this purpose. For bermudagrass in Florida, Overman et al. (1991b) obtained

$$\bar{t} = 26.0 + 3.0 \exp(-N/200) \qquad [3]$$

$$\sigma = 9.0 - 2.0 \exp(-N/200) \qquad [4]$$

$$Y_T = \frac{A_o(1 + 0.25\Delta t)}{1 + \exp\left(\frac{150 - N}{150}\right)} \qquad [5]$$

where

N = applied N, kg/ha

Δt = harvest interval, wk

A_o = yield coefficient

= 10 t/ha (optimum moisture)

= 5 t/ha (severe drought)

Typical results are shown in Figure 3 for a harvest interval (Δt) of 6 wk and optimum moisture (A_o = 10 t/ha). Overman et al. (1988b; 1990b) found that relationships similar to Equations (3) through (5) applied to data from several studies.

Phenomenological Model

Field observation of bermudagrass reveals that above-ground biomass depends upon both calendar time and elapsed time since the previous cutting. A growth model must account for these observations. For this purpose three postulates were made (Overman et al., 1989):

1. Growth is driven by an environmental function (gaussian, bell-shaped).

2. Intrinsic growth rate (under repeating daily cycle) is quadratic.

3. Net growth rate is the product of (1) and (2).

Growth rate (dY/dt) is given by

$$\frac{dY}{dt} = [a+b(t-t_i)]\exp\left[-\left(\frac{t-\bar{t}}{\sqrt{2}\sigma}\right)^2\right] \quad [6]$$

where

t_i = calendar time at beginning of growth interval, wk

a,b = constants

Other variables are as previously defined. Equation (6) may be integrated to give incremental growth

$$\Delta Y = A\{(1-2Cx_i)(erfx-erfx_i) - \frac{2}{\sqrt{\pi}}C[\exp(-x^2)-\exp(-x_i^2)]\} \quad [7]$$

where

ΔY = dry matter growth since previous cutting, t/ha

x = $\frac{t-\bar{t}}{\sqrt{2}\,\sigma}$, dimensionless

A = yield parameter, t/ha

C = curvature parameter, dimensionless

Cumulative yield (Y_n) is obtained by summing yield increments (ΔY_i), so that

$$Y_n = A\,Q_n \quad [8]$$

where

$$Q_n = \sum_{i=1}^{n}\{(1-2CX_i)(erfX_{i+1}-erfX_i) - \frac{2}{\sqrt{\pi}}C[\exp(-X_{i+1}^2)-\exp(-X_i^2)]\} \quad [9]$$

= cumulative function

Total yield for the season (Y_T) follows from

$$Y_T = AQ_T \quad [10]$$

where Q_T is Equation (9) summed over the entire growing season. Now Overman et al. (1989) established that for fixed Δt

$$Q_T = 2 + 2C\frac{\Delta t}{\sqrt{2}\sigma} \quad [11]$$

from which it follows that

$$Y_T = 2A + \frac{2AC}{\sqrt{2}\sigma}\Delta t \quad [12]$$

The phenomenological model contains four parameters ($\bar{t}$, σ, A, AC), which are evaluated from data (Overman et al., 1990a). A graph of normalized yield (Y_n/Y_T) vs time for this model does produce a straight line on probability paper (similar to Figure 2), in agreement with data. This fixes $\bar{t}$ and σ. Equation (12) predicts a linear relationship between total yield (Y_T) and harvest interval (Δt), which also agrees with data for $\Delta t \leq 6$ wk. This fixes A and AC. Typical dependence of the parameters on applied N is shown in Figure 4 for optimum moisture conditions, where the curves are drawn from Equations (3) and (4) and from

$$A = \frac{5.0}{1 + \exp\left(\frac{300-N}{150}\right)} \qquad [13]$$

$$AC = \frac{10.0}{1+\exp\left(\frac{150-N}{75}\right)} \qquad [14]$$

For severe drought, A and AC should be reduced by 50%. Equations (4), (13), and (14) can be used to estimate parameters for Equation (12). Results are plotted in Figure 5 for total yield (Y_T) vs harvest interval (Δt) for optimum moisture. Estimation should be limited to $\Delta t \leq 6$ wk.

The next step is to relate Equation (12) to plant components for bermudagrass (Overman and Wilkinson, 1989). Total dry matter (Y_T) is partitioned by

$$Y_T = L+S \qquad [15]$$

where

L = leaf mass, t/ha

S = stem mass, t/ha

Field observation indicates that stem mass increases with increase in plant age. Therefore, comparing Equations (12) and (15), we postulate that

$$L = 2A \qquad [16]$$

$$S = \frac{2AC}{\sqrt{2}\sigma}\Delta t \qquad [17]$$

According to Equations (16) and (17) total leaf mass for the season is independent of harvest interval, while total stem mass is a linear function of harvest interval. Overman and Wilkinson (1989) used field data from Georgia and Texas to support this conclusion. Since it was shown above that the parameters A, AC, and σ all depend upon applied N, and that A and AC depend upon water availability, it follows from Equations (16) and (17) that both leaf and stem mass depend upon applied N and water availability.

Forage Nutrient Concentrations

The dependence of forage concentrations of nutrients upon applied nutrients (N, P, K) and harvest interval (plant age) is now discussed. Overman and Wilkinson (1990c, d) used field data from several states (AL, FL, GA, LA, MD, NC, OK, VA) to develop quantitative relationships. These are

$$N_c = 4.50(1-0.075\Delta t)\left[1-\exp\left(-\frac{N+200}{350}\right)\right] \qquad [18]$$

$$P_c = 0.50(1-0.075\Delta t)\left[1-\exp\left(-\frac{P+95}{75}\right)\right] \qquad [19]$$

$$K_c = 5.00(1-0.075\Delta t)\left[1-\exp\left(-\frac{K+150}{450}\right)\right] \qquad [20]$$

where

N_c	=	forage N concentration, %
P_c	=	forage P concentration, %
K_c	=	forage K concentration, %
N	=	applied N, kg/ha
P	=	applied P, kg/ha
K	=	applied K, kg/ha
Δt	=	harvest interval, wk

Equations (18) through (20) apply for $\Delta t \leq 6$ wk. Response curves are shown in Figure 6 for harvest interval $\Delta t = 6$ wk.

Nutrient Removal

Nutrient removal by bermudagrass depends upon dry matter production and nutrient concentration in the grass. Dry matter can be estimated by either the empirical or the phenomenological model. This procedure involves both dry matter distribution over the season and total dry matter for the season. The empirical model involves equations such as (1), (3), (4), and (5); the phenomenological model includes equations of the type (3), (4), (8), (12), (13), and (14). Cumulative nutrient removal through the n th harvest is then estimated from

$$N_n = Y_n * N_c/100 \quad [21]$$

$$P_n = Y_n * P_c/100 \quad [22]$$

$$K_n = Y_n * K_c/100 \quad [23]$$

where

N_n	=	forage N removal through n th harvest, kg/ha
P_n	=	forage P removal through n th harvest, kg/ha
K_n	=	forage K removal through n th harvest, kg/ha

Total nutrient removal for the season is estimated by substituting Y_T in place of Y_n in Equations (21) through (23). An example of the procedure is illustrated in Figure 7 for optimum moisture, where the curves are drawn by combining Equations (5), (18), and (21). It may be noted that forage N removal is relatively insensitive to harvest interval (Δt), due to the somewhat compensating balance between dry matter production and forage N concentration from changes in Δt. Again the procedure holds for $\Delta t \leq 6$ wk.

Other Aspects

Development of models and theories is usually an evolutionary process. Work on forage models follows this pattern. There is always a struggle between simplicity and comprehensiveness. Models described above might be referred to as 'descriptive', i.e. they describe relationships among variables. They are all empirical in the sense that they involve parameters to be evaluated from data. As models go, they are relatively simple. Once the parameters are evaluated, estimates can be made on a pocket calculator.

The empirical model has been expanded (Overman et al., 1991a) to cover an NxPxK factorial experiment with bermudagrass. Data from Watkinsville, GA was used to obtain

$$Y_T = \frac{15.54}{\left[1+\exp\left(\frac{38-N}{82}\right)\right]\left[1+\exp\left(-\frac{38-P}{25}\right)\right]\left[1+\exp\left(-\frac{74-K}{47}\right)\right]} \quad [24]$$

where

N	=	applied N, kg/ha
P	=	applied P, kg/ha
K	=	applied K, kg/ha
Y_T	=	total dry matter, t/ha

A high correlation coefficient (R = 0.9884) was obtained between the model and data. Response of Equation (24) to N, P, or K follows the trend shown in

Figure 3(c). This describes the interaction among various levels of N, P, and K, and the net effect on yields.

Another characteristic of interest is the vertical (above ground) distribution of dry matter at the time of harvest. Overman and Wilkinson (1991) have shown that dry matter density of bermudagrass is described by a gaussian distribution. A typical example is shown in Figure 8, where the curve is given by

$$\rho = 0.22\exp\left[-\left(\frac{Z}{35}\right)^2\right] \qquad [25]$$

where

ρ = dry matter density, t/ha·cm

Z = height above ground, cm

Maximum density occurs at ground level and decreases rapidly with height. Overman and Wilkinson (1991) also discussed dependence of distribution on calendar time, elapsed time, and applied N. Preliminary analysis indicates that other grasses may also follow a similar distribution.

A more comprehensive model would incorporate calendar time (t), regrowth time (Δt), and vertical distance (Z) as variables in a functional (differential) equation. Efforts are continuing along this path, but, as often happens with such an agenda, progress is slow and piece-meal.

Summary

In the development of these models, the mental processes of 'guessing' and 'intuition' have played important roles. As it turns out, these same devices have been employed by famous thinkers in modern science, such as Planck, Einstein, and Feynman (Bernstein, 1973, p. 196; Feynman, 1986, p. 165). More is required than cold, hard logic.

I began this article by quoting a request from Faraday to Maxwell to explain practical implications of a theory. Let us now strive toward this goal in the present context.

Estimation procedures and practical implications for bermudagrass production may be summarized as follows:

1. Distribution of dry matter over the season can be estimated from either Equation (1) or (8). Increased applied N increases dry matter production over the entire season, particularly early in the season. Equations (3) and (4) account for this effect. It is now clear that the gaussian (exponential) term in Equation (6) describes plant response to environmental (climatic) input, and does not just describe climatic variation over the season. Otherwise, applied N would not affect $\bar{t}$ and σ.

2. Dependence of total dry matter production on harvest interval is given in Equations (5) and (12). Applied N and water availability is accounted for through either Equation (5) or Equations (13) and (14).

3. Leaf and stem dry matter are estimated from Equations (16) and (17), which incorporate effects of applied N and water availability. It was concluded that for a fixed harvest interval total leaf mass is independent of harvest interval, while stem mass increases linearly with harvest interval, up to intervals of 6 wk. This probably accounts for the decrease in crude protein with plant age.

4. Forage nutrient concentrations (N, P, K) can be estimated from Equations (18) through (20), which incorporate applied nutrients (N, P, K) and harvest interval (Δt). Concentrations show a linear decrease with plant age (up to 6 wk) and exponential increase with applied nutrients.

5. Forage nutrient removal (N, P, K can be estimated from Equations (21) through (23), both during the season and over the entire season. Removal of applied N is relatively insensitive to harvest interval. Longer intervals produce more dry matter, but of lower N concentration. The two effects somewhat compensate each other.

6. Combined effects of applied N, P, and K are accounted for by Equation (24). Since this equation contains seven parameters, a large data base from a factoral experiment is required. Additional data sets need to be examined to confirm Equation (24). The approach does appear reasonable, since a correlation coefficient of 0.9884 was obtained.

7. The vertical distribution (above ground) of dry matter is described by Equation (25), a gaussian function. Maximum density occurs at ground level, with a rapid decrease with height. In general, the distribution depends upon calendar time, regrowth time, and applied N.

8. It remains to develop a more comprehensive model which contains calendar time (t), regrowth interval (Δt), and height above ground (z) as independent variables.

9. Concepts and procedures described here are relevant to forage production (quantity and quality), environmental concerns (nutrient recovery and losses), and sustainable agriculture.

10. Continued cooperation among scientists and engineers should be mutually beneficial. At least I have found it so.

Acknowledgement

The author acknowledges assistance from many individuals throughout these investigations (since 1984). Particular appreciation is extended to Stan Wilkinson (Southern Piedmont Conservation Research Center, USDA-ARS) for continuing collaboration and for keeping a modeler's thinking on track through insights gained from many years in the field. Thanks are also due to Glenn Burton (Coastal Plains Experiment Station, USDA-ARS) for many stimulating conversations over the years and for inspiration derived from over 50 years of pioneer work in forage production.

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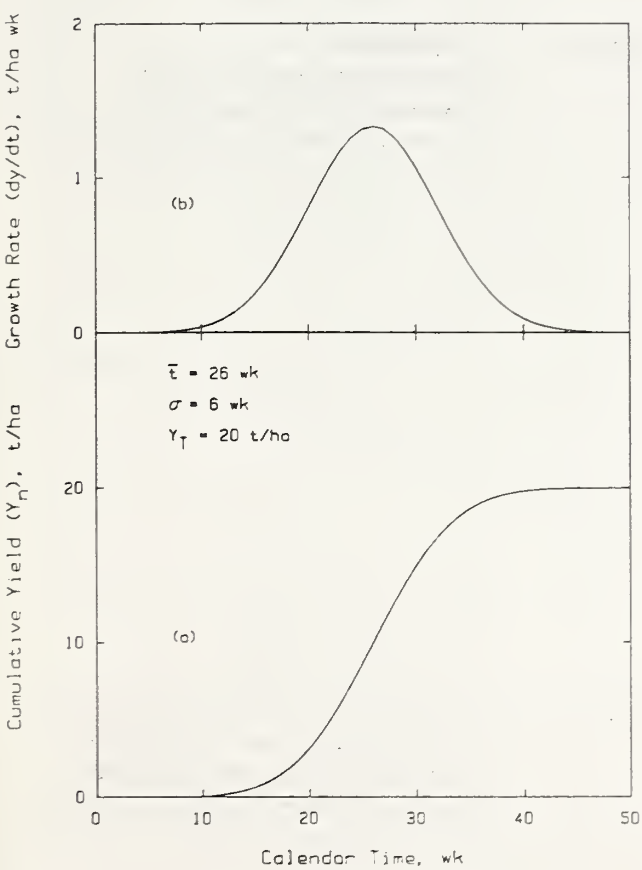

Figure 1 Response of Cumulative Yield and Growth Rate of Bermudagrass to Calendar Time.

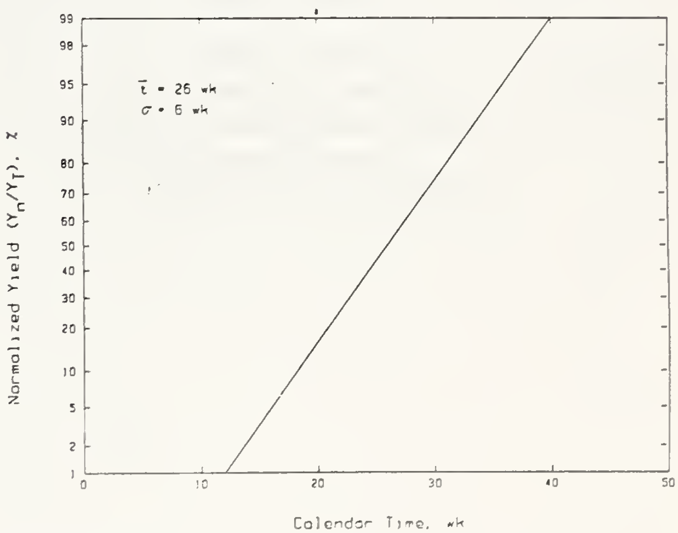

Figure 2 Response of Normalized Yield of Bermudagrass to Calendar Time. Line Drawn from Equation (1).

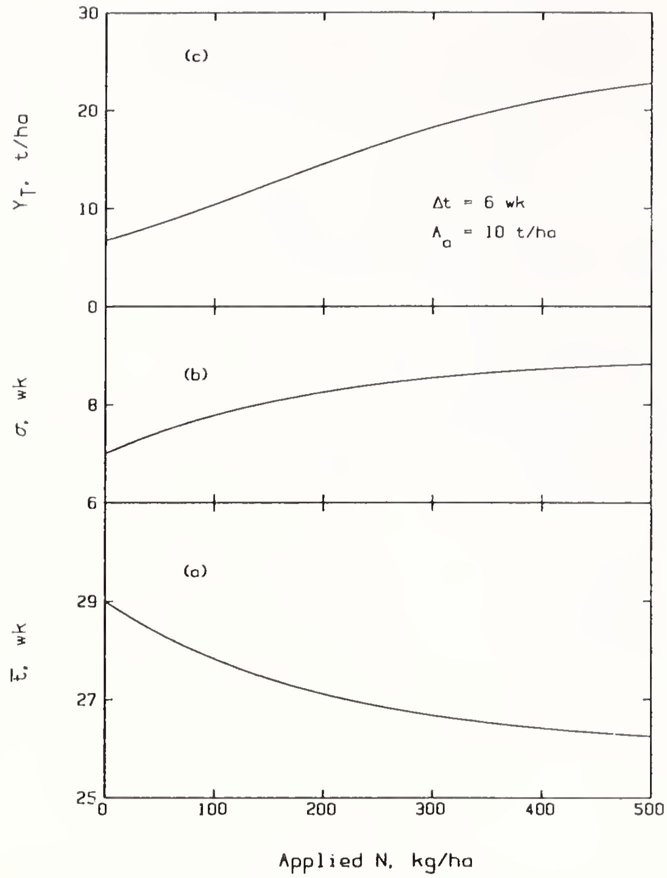

Figure 3 Dependence of Empirical Model Parameters on Applied N. Curves Drawn from Equations (3) through (5).

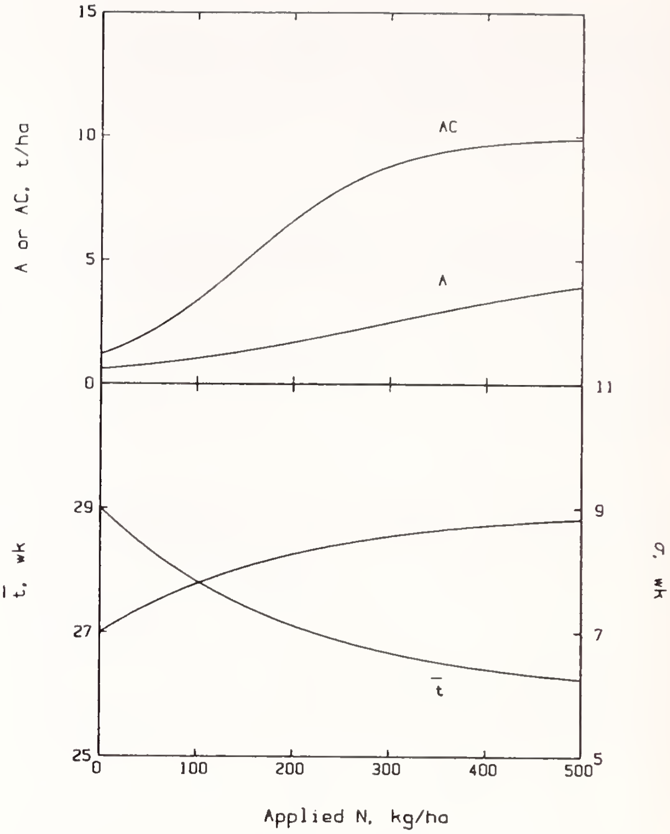

Figure 4 Dependence of Phenomenological Model Parameters on Applied N. Curves Drawn from Equations (3), (4), (13), and (14).

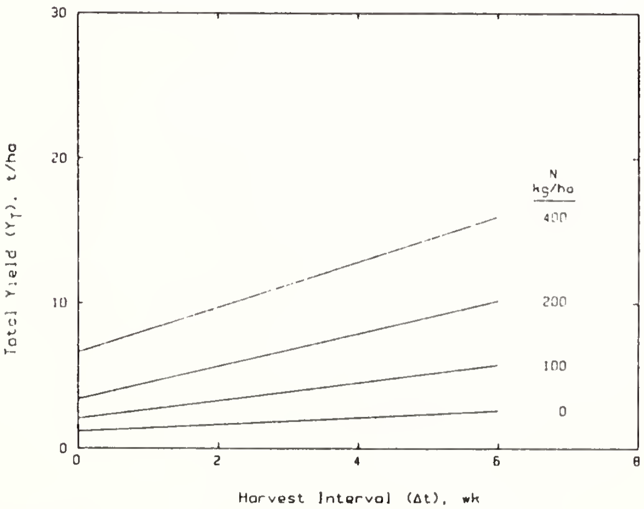

Figure 5 Dependence of Total Yield of Bermudagrass on Harvest Interval. Lines Drawn from Equation (12).

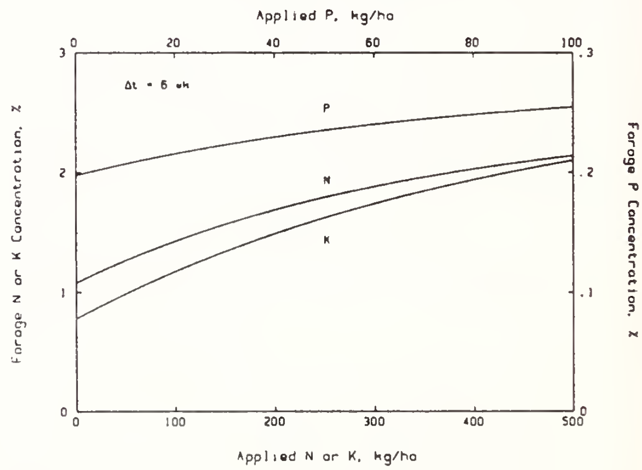

Figure 6 Response of Forage Nutrient Concentrations to Applied Nutrients for Bermudagrass. Curves Drawn from Equations (18) through (20).

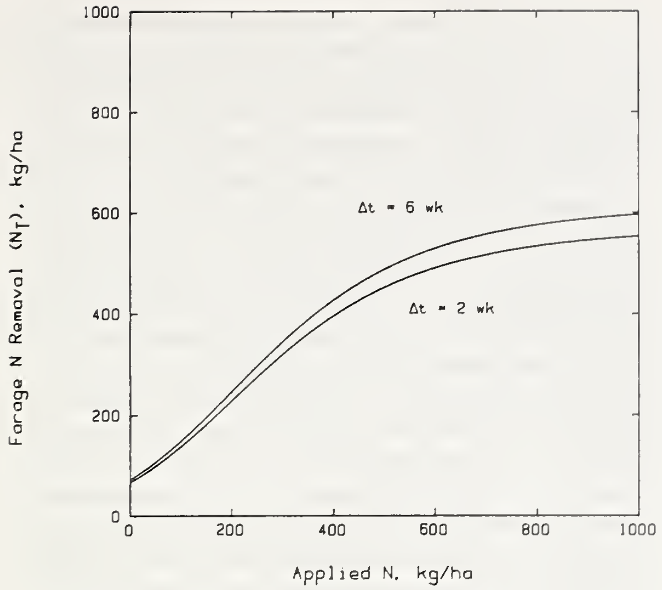

Figure 7 Response of Forage N Removal to Applied N for Bermudagrass. Curves Drawn from Equation (21).

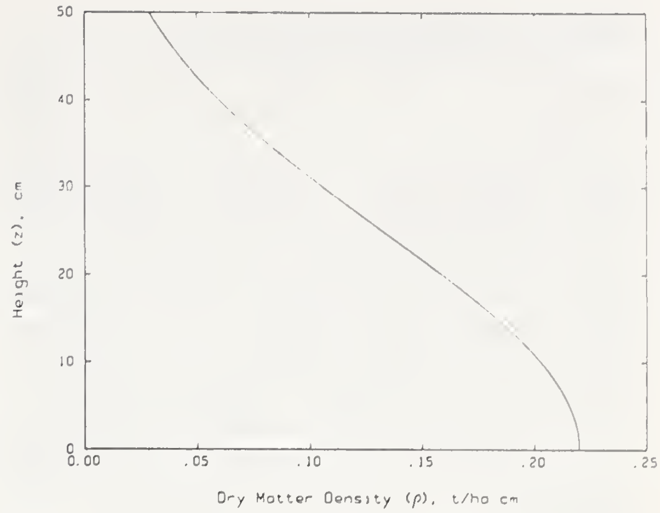

Figure 8 Dependence of Dry Matter Density on Height Above Ground for Bermudagrass. Curve Drawn from Equation (25).

ENVIRONMENTAL IMPLICATIONS OF ANIMAL WASTE APPLICATION TO PASTURES[1]

J.M. Phillips, H.D. Scott, and D.C. Wolf[2]

Land application of animal wastes (with and without litter) has been a worldwide agricultural practice for many years. Animals are as important as crops in U.S. agriculture. As sources of farm income, animal commodities rank first or second in 41 states (CAST, 1988). Nationally, the meat and poultry industry employs 370,000 people with a payroll of $4.5 billion. Economically, animals represent a value-adding phase of livestock-crop systems.

Animal production practices have changed in response to the need for greater production efficiency and to the increase in per capita consumption. These changes include an increased number of animals per production unit and confinement feeding of livestock. The accumulated wastes at these operations are point sources of potential pollution. Consequently, improvements in waste management and control are essential (Loehr, 1972).

Although the use of animal wastes can pose potential problems, they also contribute significantly to the U.S. economy in terms of fertilizer value. Over 3.6 million Mg of poultry litter is produced annually in the U.S. About 1 million Mg of this (108,840 Mg of nitrogen) is produced in the southeastern U.S. (Fogg, 1978). Poultry litter application returns to the soil a large proportion of the plant food needed by pasture species such as nitrogen (N), phosphorus (P), potassium (K), and many micronutrients. Additionally, manures supply humus-forming materials that improve the tilth or physical condition of both light and heavy soils (Hileman, 1967; Chessmore, 1979). Beneficial effects of improved soil physical condition include improved aeration, greater ease in preparation of good seedbeds, more rapid germination of seeds, improved water-holding capacity, and increased activity of soil microorganisms. Manure applications generally result in greater water infiltration and less water runoff. Heavy manure applications increase soil pH, electrical conductivity, available P, exchangeable cations, total N, NH_4-N and, in most cases, NO_3-N (Siegel et al., 1975). Thus, soil productive capability is generally improved chemically, physically, and biologically by the application of moderate amounts of manure.

Public concerns about animal-based systems include: (1) diet and health, (2) land and resource availability, (3) animal welfare, (4) use of biotechnology and other scientific interventions, and (5) environmental impacts (Baker et al., 1990). Many factors, such as manure composition (form and availability), nutrient transformations after application, soil chemical and physical properties, forage species, date of application, etc., must be considered when assessing the environmental implications of manure application to pastureland. To date, most of the attention has been focused on N from manures and its impact on the environment (primarily plant uptake, surface runoff, and leaching losses to groundwater). The objective of this paper is to discuss the environmental impacts of animal waste application to pastureland in the southeastern U.S.

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SEDIMENT LOSS

Burns (1980) stated that one of the major opportunities that confronts agriculture today, and also one of the major responsibilities, is to maintain high production and high incomes, and low soil and water losses. Grasslands are the type of land best suited to receiving animal wastes because their permanent vegetative cover effectively restricts soil losses (Thorup and McVickar, 1974). Water quality management plans have been developed in every state. It is estimated in the Resource Conservation Act (RCA) of 1972 that annual soil losses are much higher in cropland than land under permanent cover in all capability classes (Table 1) (Mannering, 1980). Livestock wastes can create water quality problems when not managed properly (Mannering, 1980). Spreading wastes on frozen or sloping wet soils adjacent to or near streams can result in their transport into the stream. A practice that can create groundwater problems is the application of more N in the manure than that required by the crop to be grown. The major mechanism in this situation is the leaching of mobile nitrates below the root zone. When N is applied to pasture, its efficiency declines as the applied rate increases.

COMPOSITION OF ANIMAL MANURE

Animal wastes can be used very effectively as pasture fertilizer, but several characteristics must be recognized (Wilkinson, 1979): (1) wide variability in water and plant nutrient content, (2) low plant nutrient content as compared to commercial fertilizers, (3) high percentage of carbon, which may be used by small animals and microorganisms in the soil, and (4) higher costs for handling and spreading per unit of plant nutrients than for commercial fertilizers (due to the high water and carbon contents).

Numerous authors have assessed the nutrient composition and/or variability of animal wastes (Wilkinson, 1979; Burns et al., 1990; Gale et al., 1991). Edwards and Daniel (1991) summarized the nutrient composition and variability of poultry wastes (Table 2). A thorough nutrient analysis is essential to predict the plant nutrient input from a given application to pasture. The nutrient content of animal manures varies with climate, feed composition, production phase, and management practices (Wallingford et al., 1975). The fertilizer efficiency of animal manures on pastureland can be affected by: (1) animal size and species, (2) ration fed, (3) housing and rearing arrangement, (4) storage, hauling, and spreading methods, (5) rate of manure applied, (6) forage species grown, (7) soil series, (8) crop cultural management, including irrigation, fertilization, and harvesting, and (9) climate (Wilkinson, 1979).

FORAGE YIELD AND NUTRIENT RECOVERY

Animal wastes can be applied to pastureland as a fertilizer with several goals: (1) to promote forage yield and quality, (2) to build up soil nutrients, and (3) to apply the waste in a cost effective and environmentally safe manner. Of all plant nutrients, N is recognized as the production nutrient, and yield is often an indirect assessment of its efficiency of use. A significant amount of forage yield data in response to animal waste applications has been published. The most significant and desirable loss of N as a result of animal waste application is plant uptake. The animal wastes to be discussed are poultry litter and swine lagoon effluent, which have been investigated more in the southeastern U.S. than other animal wastes.

Hileman (1965 and 1973) reported that yields of orchardgrass in Arkansas were increased up to, but not above, poultry litter rates of 9 Mg/ha annually. Rates above 17.9 Mg/ha suppressed grass growth. Applying 4.5 to 6.7 Mg/ha of average-analysis poultry litter would adequately supply major plant food elements (N-P-K) required for orchardgrass and tall fescue meadows and pastures. In a 4- to 5-year study in Arkansas, Huneycutt et al. (1988) found that 'Tifton 44' bermudagrass yields increased linearly with poultry litter rates where 13.3 Mg

of forage/ha was observed at the highest application rate (13.5 Mg/ha/year). In this trial, the 13.5 Mg rate resulted in an average application of 504-376-444 kg of total N-P_2O_5-K_2O per hectare and produced forage dry matter equivalent to bermudagrass receiving between 224 and 336 kg/ha of N (plus associated P and K) from commercial fertilizer. Assuming that only 60% of the organic N in poultry litter is mineralized during the first year of application (Castellanos and Pratt, 1981), the yield responses to the two sources of fertilizer on the basis of plant-available N were similar. Tall fescue production also increased linearly with poultry litter rates. The 13.4 Mg/ha litter rate produced 7.77 Mg of dry forage/ha. At the 13.4 Mg/ha rate, yields were comparable to tall fescue receiving 323 kg N/ha/year. This was the same result found when comparing the two fertilizer sources for bermudagrass.

Table 1.
Estimated national average of annual sheet and rill erosion by land use and capability class.

Class	Slope	Cropland	Pasture land	Native pasture	Forest land
	- % -	Mg/ha/year			
I	< 2	6.7	0.7	2.5	0.2
IIe	2-6	11.2	1.6	2.0	0.4
IIIe	6-12	15.5	3.8	5.4	1.1
IVe	12-18	19.5	6.0	9.9	2.2
VIe	18-24	32.9	13.2	13.9	3.8
VII & VIII		34.5	22.4	28.2	5.6

Table 2.
Primary nutrient content of animal manures from various waste management systems (representative values).

Type of livestock	Waste system	Dry matter	Primary N	Plant P_2O_5	Nutrient K_2O
		%	kg/metric ton (wet basis)		
Broiler	Solid with litter	75	30	26	18
Hens	With litter	75	21	33	17
Hens	Battery	29	17	14	7
Turkeys	Litter	58	19	15	9
Swine	Farmyard manure (FYM)	23	6	6	4
Beef	Feedlot	52	11	10	15
Dairy	FYM	23	6	3	7
			kg/1000 liters		
Poultry	Liquid slurry	8	6	5	2
Swine	Slurry	4	4	2	2
Beef	Oxidation ditch	3	3	2	5
Dairy	Slurry	4	3	1	3

Dudzinsky et al. (1983) evaluated the fate of NH_4NO_3 and poultry litter applied to 'Coastal' bermudagrass in Georgia. Total dry matter yields where poultry litter had been applied over 7 years were 82 and 98 Mg/ha/yr where 699 and 1397 kg N/ha/yr was applied, respectively. Apparent N recoveries for these treatments were 71% and 48%. The total forage yield was 61 Mg/ha/yr where 1344 kg N/ha/yr as NH_4NO_3 was applied. The apparent N recovery for this treatment was 59%. Nitrogen losses in the soil-water percolate from the 1344 kg N/ha/yr treatment as NH_4NO_3 accounted for over 25% of the applied N, while leaching losses from poultry litter application (1397 kg N/ha/yr) were less than 5%. Additionally, the continual application of NH_4NO_3 (448 kg N/ha/yr) increased the amounts of percolate water. Nitrate-N concentrations reached a peak of 40 ppm at the end of the fourth year, indicating that NO_3 was accumulating and had not reached a steady state.

Wilkinson et al. (1985) measured the effects of interseeding rye into Coastal bermudagrass where poultry litter was applied. Where 45 Mg/ha/yr of poultry litter was applied, yield and N recovery were increased by interseeding rye. Percolate-water NO_3 losses were also reduced dramatically, and surface runoff losses of NO_3 were minimal.

Swine manure effluent has been investigated recently for use as a fertilizer on Coastal bermudagrass in North Carolina (Burns et al., 1990). Three effluent loading rates were evaluated for 11 years where 335, 670, and 1340 kg N/ha/yr were applied. Annual dry matter yields of 11 and 15 Mg/ha were realized at rates of 335 and 670 kg N/ha/yr. No yield advantage was found using the 1340 kg N/ha/yr rate compared to the lower rates. The high rate caused unstable stands and produced forage in latter years that had potentially toxic concentrations of NO_3-N if fed to young or pregnant ruminants. Large quantities of nutrients remained in the soil at the medium and high rates. The high rate created a potential for groundwater contamination where appreciable NO_3-N levels were found (King et al., 1990). In some years, the medium rate resulted in appreciable NO_3-N accumulation. Mehlich 1-extractable P increased with increased rates. High P concentrations in the surface soil increased the potential for runoff of P. The highest runoff potential would occur if the area were planted to a clean-tilled crop, resulting in erosion.

A field study was initiated in 1990 at Fayetteville, Arkansas, where poultry litter was applied to a tall fescue meadow at 0 and 9 Mg/ha (Scott et al., 1991). Parameters measured include forage dry matter yield, plant N and P contents, soil water pressure at 30-, 60-, 90-, 120-, and 200-cm depths in the soil profile, soil water content and temperature at the 10- and 30-cm depths, NO_3 concentration in soil solution extractors at 200 cm, and volatilization rates of NH_3. The soil is a Captina silt loam (typic Fragiudult).

A tall fescue yield of 16.1 Mg/ha was observed in 1990 where 9 Mg/ha of poultry litter was applied. This was about 4.7 times more forage than the control where no fertilization occurred.

Seasonal concentrations of N and P in the treated forage consistently had higher concentrations of N and P than the control forage. During the season, the forage N concentrations ranged from 2.0 to 4.9% in the treated plots and from 1.7 to 3.0% in the control plots. For the year the average N concentration was 3.4 and 2.2% for the treated and control tall fescue, respectively. For P the concentrations ranged from a low of 0.21 to a high of 1.00% in the treated plots and from 0.22 to 0.41% in the control plots. The seasonal average concentrations were 0.48 and 0.30% for the treated and control plots, respectively. Thus, the treated plots had an average of 1.6 times higher N and P concentrations than did the control plots.

The seasonal accumulation of N and P increased in the treated forage as a result of an increase in yield and concentration. At the end of the season, a total of 575 and 75 kg/ha of N was found in the treated and control forage, re-

spectively. For P the total amounts accumulated were 85 and 12 kg/ha in the treated and control plots, respectively. Thus, the forage treated with 9 Mg/ha of poultry litter accumulated about 7-8 times more N and P than did the control plots.

Dry matter production in the treated plots had little significant influence on the soil water pressures at the 120- and 200-cm depths. Rainfall during July and August was less than 5 cm, which was considerably below the potential evapotranspiration for the area. As a result, the forage extracted water from the soil profile at these depths by late July. The greatest changes in pressure due to extraction occurred at the shallow depths. For example, at the 120-cm depth the soil water pressures decreased from about -100 mb of water pressure in mid July to about -500 mb of water pressure during early October. Similarly, at the 200-cm depth the soil water pressure decreased from about -100 mb in mid July to about -300 mb in early October. The increased soil water pressure during mid October was due to the higher incidence of rainfall during this time. These data also indicate that, for tall fescue grown on this soil, the upper limit of extractable water was about -100 mb, and that, under drought conditions during the summer, water is extracted from the soil at relatively deep depths.

The hydraulic gradients can be used to determine the magnitude of the driving force of water in the soil profile as well as the direction of flow. For the most part the hydraulic gradients were near +1.0 cm/cm during the spring, early summer, late fall, and winter, which indicates that water was moving down below the root zone. During the drought, however, the hydraulic gradients decreased to -2.0 cm/cm by mid September and early October. These results show that for most of the year water was moving down in the soil profile, and therefore, would be carrying water soluble ions and molecules such as nitrate toward the groundwater table. Under these conditions, leaching of nitrate to the groundwater could be significant, particularly if the concentration in the soil solution is higher than normal. However, during the drought, the direction of water flow was upward, which indicates that water was moving into the root zone from below. Under these conditions, leaching of nitrate to the groundwater would be negligible.

Seasonal concentrations of nitrate in the soil solution below the root zone indicate that nitrate concentrations in solution of the treated plots tended to be higher than in the control plots throughout the year. The peak concentrations in solution came soon after the application of the poultry litter. The average solution concentration of nitrate was 1.5 times higher in the treated plots than in the control plots.

Ammonia volatilization was measured from poultry litter applied at five rates (from 0 to 90 Mg/ha) to tall fescue in May. While volatilization was rate dependent, the largest amount of NH_3 volatilization was 14% of the total N applied at the 90 Mg/ha rate.

These field studies along with others have documented the loss of waste-applied nutrients through plant removal, leaching, and surface runoff. Several N transformation processes (NH_3 volatilization and denitrification) play a vital role in accounting for N loss as a result of waste applications.

AMMONIA VOLATILIZATION

Surface application of poultry manure can result in substantial loss of N in the gaseous form of NH_3. Generally, the greatest loss occurs during the first week following application. Atmospheric conditions that favor NH_3 volatilization include high temperature and rapid air exchange at the soil surface, e.g., windy conditions (Hargrove, 1988). Soil conditions that favor NH_3 loss include moist soil, low hydrogen ion buffering capacity, low cation exchange capacity, high initial pH, and high urease activity (Ferguson et al., 1984; Reynolds and Wolf, 1987). High rates of waste application and dense stand forage biomass could also favor NH_3 volatilization.

In laboratory and field studies, Wolf et al. (1988) reported that 37% of the total N in hen manure was lost as NH_3 in 10 and 11 days, respectively, when the manure was surface-applied to either a Captina silt loam or a Bowie fine sandy loam (Figs. 1 and 2). If the hen manure was incorporated, the losses were ≤ 8% under the same conditions. Crane et al. (1981) also reported substantial losses of NH_3 from surface-applied hen manure. In a 5-day study, they found that 49 to 75% of the total N contained in the manure was lost as NH_3.

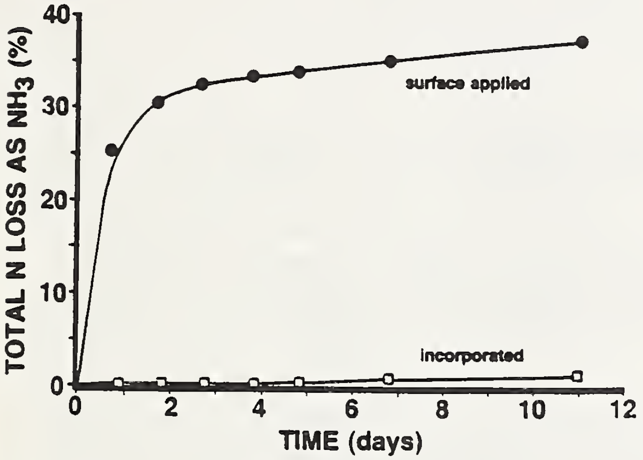

Figure 1. Percentage of the total nitrogen in hen manure that was volatilized as ammonia during a 10-day laboratory study. The application rate of manure was equivalent to 6.8 Mg/ha (dry weight basis) and the waste was incorporated or applied to the bare soil.

The ability of the soil to retain NH_3 is important in reducing NH_3 loss (Reynolds and Wolf, 1987). In studies conducted to evaluate NH_3 volatilization from surface-applied urea, preventing the N from contacting the soil increased NH_3 volatilization (Reynolds and Wolf, 1988). Beyrouty et al. (1988) also reported that, when urea granules were not in contact with the soil and were retained on crop residue, the amount of volatilization increased. The same mechanisms would probably operate to increase NH_3 volatilization when poultry litter or manure is applied to a dense canopy in that the litter or manure would not be in direct contact with the soil.

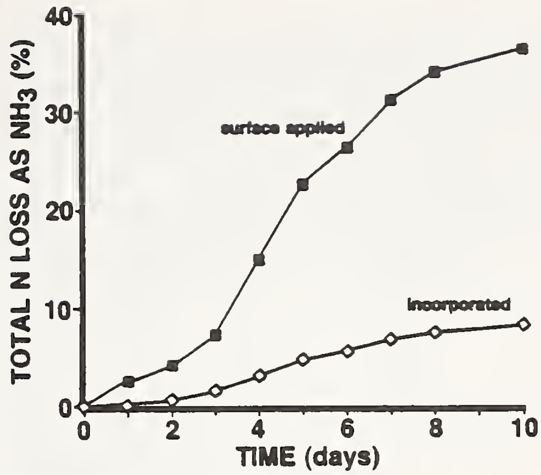

Figure 2. Percentage of the total nitrogen in hen manure that was lost as ammonia during an 11-day field study. The manure was either applied to the bare soil surface or incorporated at rates of 3.4 or 6.8 Mg/ha (dry weight basis).

DENITRIFICATION

Denitrification is an additional mechanism that can result in N loss from soil amended with poultry litter or manure. Denitrification is mediated by soil microorganisms and occurs only when NO_3 is present, the soil is anaerobic, and carbon is available for microbial activity (Paul and Clark, 1989). In waste-amended soils, aerobic conditions must be present for sufficient time to allow organic N in the poultry waste or to be converted to NH_4 and then oxidized to NO_3. Once NO_3 is produced, if the soil becomes anaerobic due to irrigation or precipitation, and if sufficient microbially available carbon is present, denitrification can be rapid (Tiedje et al., 1989).

In a laboratory study, poultry litter was surface applied to a Captina silt loam at rates of 0 and 9 Mg/ha and incubated under aerobic conditions for 7 days and subsequently flooded (Wolf et al., 1988). Nitrate disappearance was rapid and substantial (Table 3). Longer aerobic incubation times resulted in greater accumulations of NO_3, but flooding did not result in complete denitrification due to a lack of available carbon for microbial activity.

Table 3.
Influence of flooding on the loss of NO_3-N from a Captina silt loam amended with 0 and 9 mg/ha poultry litter. The soil was incubated under aerobic conditions for 7 days before it was flooded.

Litter rate	Flooded time	Nitrate-nitrogen in the soil
Mg/ha	days	mg/kg
0	0	22
0	2	18
0	3	12
9	0	45
9	2	13
9	3	6

SUMMARY

Siegel et al. (1975) stated, "Animal manures utilized effectively as fertilizers for crop production promote efficient recycling of limited mineral and energy resources available for food production and provide an outlet for large quantities of waste generated by commercial animal production." This statement certainly applies to today's situation. Future research must emphasize application rates suited to crop production needs, date of application, improved application methods, and the use of a balance sheet to document losses of both macro- and micronutrients. A more thorough understanding of the transformations of these nutrients is needed.

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PHOSPHORUS INTERACTIONS WITH MAGNESIUM, CALCIUM AND POTASSIUM UPTAKE AND TRANSLOCATION: A MINIREVIEW

T.M. Reinbott and D.G. Blevins

Grass tetany or hypomagnesemia is a metabolic disorder in ruminents associated with low blood serum Mg and in some instances Ca (Grunes et al, 1970). Wheat pasture poisoning (hypocalcemia) is similar but associated mainly with low blood serum Ca levels although low Mg is sometimes present (Stewart et al, 1981). Grass tetany and wheat pasture poisoning occur mainly in the spring during a flush of growth when soil is cool and wet. Magnesium forage concentrations less than 2.0 g/kg are considered to be grass tetany prone (Kemp, 1960), which is adequate for plant growth. A K/(Mg+Ca) equivalents ratio of 2.2 or greater is also associated with high instances of grass tetany (Kemp and t' Hart, 1957; Butler, 1963).

Magnesium and Ca uptake and translocation is antagonized by other cations. High levels of K and/or ammonium depress Mg and Ca uptake (Claassen and Wilcox, 1974) and K depresses Mg and Ca translocation from the roots to the shoots of the plant (Ohno and Grunes, 1985). Minotti et al (1969) treated wheat seedlings with various nitrate solutions containing various cations as counterions and found that Mg was the only cation that effluxed from the roots. Other studies have shown that influx of Mg and Ca is passive while efflux is active (Macklon, 1975; Macklon and Sim, 1976; Stok et al, 1981). Unpublished data by Reinbott and Blevins with hydroponically grown wheat seedlings show that Mg and Ca efflux increases as the amount of ammonium and K supplied to the roots is increased.

Reinbott and Blevins (in press) grew wheat seedlings in hydroponic in solutions with nutrient concentrations based on available nutrients found in a typical fertile, midwestern alfisol (Barber, 1984). The initial solution contained 25 µM P and the wheat seedlings depleted the P within in a few hours and net efflux of Mg and Ca resulted. The P concentration was then varied from 25-150 µM at 25 µM increments. When P concentration in the nutrient solution was below 75 µM there was a net efflux of Mg and Ca, but as P was increased up to 150 µM there was linear uptake of both Mg and Ca. In these studies P was an important factor in stimulating net uptake of Mg and Ca, while K uptake was increased only slightly.

Phosphorus is important in the trans-location of Mg and Ca from roots to shoots of plants. Skinner and Mathews (1990) found that Mg leaf concentration of grapes grown in a vineyard were increased from 0.11% to 0.36% when P fertilizer was soil applied at 0.14 kg P/vine. In subsequent greenhouse studies in soil they found that the concentration of Mg in xylem sap of grape, when fertilized with P, was twice that of -P fertilized plants and the -P plants had twice the Mg root concentration. They concluded that Mg uptake and translocation from roots to shoots were dependent upon P supply to the root and that Mg translocation was more dependent than uptake on P supply. Reinbott and Blevins (in press) grew wheat plants in a greenhouse in perlite pots for 40 days with solution P levels of 50,100, 200 and 400 µM. When P concentration in the nutrient solution was increased from 50 to 400 µM Mg concentration in the shoot increased from 2.4 mg/g to 3.1 mg/g and Ca shoot concentrations increased from 2.6 mg/g to 3.1 mg/g even though dry matter also increased. Phosphorus concentration increased with each P increment from 1.6 to 5.0 mg/g. Thus Mg and Ca uptake and translocation exceeded growth as solution P increased, however K did not and resulted in a decrease in K concentration (from 23.1 to 16.4 mg/g) in the shoot from dilution. The increase in Mg and Ca and decrease in K concentrations would then lead to a decrease in the likelyhood of the forage to cause grass tetany. In hydro-ponically grown rice, Fageria and Baligar (1989) found similar increases in shoot Mg and Ca concentrations when P was increased from 50 to 400 µM.

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In greenhouse studies using soil, Mg influx and leaf concentration were increased in soybean (Hallmark and Barber, 1984) and barley (Follett and Reichman 1973) when up to 100 mg/kg P was added to the soil. In each case a stimulation of dry matter occurred as a result of P fertilizaton, but Mg translocation exceeded growth. However, K concentration decreased in leaf tissue in both studies and Ca concentration decreased in barley tissue probably from dilution. In tropical pasture legumes, Andrew and Robins (1969) found increases in leaf concentrations of both Mg and Ca as P fertilization increased. In all studies discussed thus far initial soil P fertility was rather low and plants responded with increased P shoot concentration along with increase Mg and/or Ca concentration. However, Reneau *et al.* (1983) fertilized forage sorghum in field plots that tested medium in P with various levels of P and K fertilizers of up to 116 and 240 kg/ha, respectively. As the amount of P fertilizer applied was increased, Mg and Ca concentration in the shoot tissue increased significantly, whereas P concentraton in the shoot did not increase. Increasing the P fertility also helped off-set the decrease in Mg and Ca concentrations associated with the additon of large amounts K fertilizer. Similar results were found by Hallmark and Barber (1984) when 100 mg/kg K was added to soybean.

Results discussed in this review provide evidence that P is important for Mg and Ca uptake and translocation to the aerial portions of the plant. Increases in Mg and Ca translocation often exceeds that of dry matter accumulation. In cool, wet soils where P availability is often limited (Barber, 1984), less Mg and Ca uptake and translocation may occur and an accumulation of K which may lead to a higher incidence of grass tetany or wheat pasture poisoning.

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APPLYING ECONOMICS TO FORAGE-LIVESTOCK SYSTEMS--ISSUES, PROBLEMS, AND NEEDS

Greg Clary[1]

Managers of agricultural operations have long understood the direct relationship between improved efficiency and increased profits. Continuing volatility of market prices and costs of inputs have created concern and the need for careful analysis of production systems prior to making decision about resource allocation or new enterprises. This especially is true in the cattle business, where producers and others have seen an erosion of beef's market share by poultry products.

Cattlemen have been challenged to lower costs of production in order to provide consumers with more price competitive products while improving producers' profitability. This is the main thrust of the Integrated Resource Management (IRM) program. IRM is one of a number of management programs aimed at improving efficiency in beef cattle production. This national program emphasizes the application of sound farm and ranch management principles by teams of specialists using systems approaches to improve efficiency and increase profits by assisting producers with more effective planning and decision making. Agricultural economists bring unique production, financial, and marketing management tools to these teams. This paper briefly highlights several opportunities for collaborative work especially between agricultural economists, agronomists, nutritionists, and others involved in investigating pasture/forage production and utilization issues.

It is with IRM and systems approaches in mind that discussions on applying economics to forage-livestock systems are presented. Economic issues involving production and utilization of forages, problems with economic evaluations of experimental data, and areas needing more attention are mentioned. Presentation of research results is minimized as the main purpose is to generate interchange between scientists from several disciplines concerned with improving efficiency in forage-livestock production and utilization systems. It is important that production scientists have a basic understanding and appreciation for economic aspects of problems being investigated.

WHY COMPLICATE MATTERS WITH ECONOMICS?

Economic principles provide an excellent foundation and basis for assigning resources to their highest valued use in an effort to run efficient operations and reach maximum profitability. Producers have their own unique package of resources at their disposal. This package generally includes land, labor, capital, management, and information.

Cattle producers must look to their own operations to find areas in which the most improvement can be made. Analyses of typical East Texas cow/calf operating budgets generally shows that over 40 percent of all economic costs (operating, capital investment, ownership, machinery, labor, and land) are attributable directly to pasture and forage production. More importantly, these costs comprise over 85 percent of all variable costs, those over which managers have the most control. This likely is typical of many cow/calf systems in the South, where pastures and forages play a vital role in beef production. These relationships imply that cow/calf producers should be assigning a large share of their management time and other resources to ensuring efficient forage production and utilization.

Production established while considering only physical relationships normally is not judged economically to be at profit maximizing levels. Consideration of revenues and expenditures in the evaluation of input usage, in the combining of inputs for production, and in selecting enterprises is critical to long-term success of farms and ranches.

There is no reason to outline in detail analytical tools supplied by agricultural economists to management teams. These are explained well in a variety of farm and ranch management texts, journals and applied reports, and many other sources.

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Financial management tools including accrual income statements, operating budgets, cash flows, and partial budgets, along with production economic concepts including equimarginal principles, diminishing returns, optimization, and others, are of special interest in managing farms and ranches.

USING THE SYSTEMS APPROACH AS A GUIDE

Because agricultural economics is a social science, one sometimes finds its followers viewing problems with more holistic perspectives than professionals trained in basic or applied science inquiry. However, economists utilizing an entirely holistic approach are rare. Many are uncomfortable with analyses which takes them beyond hard systems models as they then begin having to explain nonquantifiable factors introduced by human elements of management.

Wilson and Morren, Jr. (1990) suggested a rather unique holistic systems approach to solving agricultural and natural resource problems. A systems methodology is based on the notion that there are interactions among organizations of people and biological and physical properties. This approach to tackling problems implies paying attention to such interactions, to controls that are present, to communications between parts, to properties that emerge as a result of real or projected interactions, to kinds of operations that are present or absent, and to impacts of interactions between the parts on the environment.

Central to their approach is a holistic integration-reductionist spiral of methodologies which effective problem solvers must learn to spiral up and down, and which depends on the kind of problem or situation faced. Four major phases are noted in this learning spiral. These phases provide a structure for discussing economic applications to forage-livestock production and utilization.

Looking at Soft or Human Activity Systems

For this paper, human activity systems refer to people that impact production systems. These owners, managers, and others differ fundamentally from the natural and designed systems that represent activities being conducted within the overall farm or ranch context. The latter have a degree of objectivity and identity independent of observers' points of view. On the other hand, introducing human aspects into agricultural situations naturally makes them complex and ill-defined. Professionals working at this level must deal with producers goals and objectives, perceptions, preferences, prejudices, and other features. Additionally, they must be concerned with environmental issues, activists, bureaucracies, competitors, and any other groups or individuals which in some way may control the efficient operation of systems being studied or developed.

The human aspect of forage-livestock systems management oftentimes is neglected by researchers and extension specialists. Yet, it easily can provide explanations for producers choosing one course of action over another with or without regard for professional recommendations, efficiency, or profitability. Examples might be as elementary as utilizing herbicides instead of mechanical means to control weeds in pastures. Adoption of spraying technologies is slow in many areas even after agronomists explain the payoff in terms of time and forage production and economists discuss returns of from $5 to $10 per dollar expended. Recommendations for improved efficiency in livestock production, meeting with resistance from many producers, include reproduction and production strategies to shorten calving periods, castrating and implanting calves, and coordination of livestock and forage production for maximum economic utilization.

An inordinate amount of time need not be spent with the soft systems level as most researchers and extension specialists However, it is very important to remember that all research results must be evaluated in the context of human systems. Implications and impacts of results ultimately are judged by affected groups and will be adopted or rejected based on individual specific criteria and points of view.

Modeling with Hard Systems

General procedures associated with the hard systems phase of the spiral are found, with minor variations, in most systems engineering, systems analysis, operations research, and simulation texts. These procedures are best suited for tackling problems involving those biological, physical, mechanical, and human activity systems for which it is realistic and appropriate to define clear-cut quantitative goals. An appropriate example is a profit maximizing model of an integrated farm or ranch operation.

Several production functions or relationships can be combined with input costs and/or market prices into models measuring cost effectiveness or profitability. This phase of systems thinking can be characterized by evaluation of multiple interrelated enterprises. Models often provide possible mechanisms for choosing between alternative strategies.

Methods for addressing economic components of problems at the hard systems level range from comparing financial statements to more sophisticated models including linear programs and simulations. It is well accepted that evaluations of profitability, costs of production, cash flow, and other economic relationships are enhanced if economists are involved as projects are initiated. However, this quite often is not the case. Economists oftentimes are challenged by colleagues to introduce economic principles to completed production-oriented projects. The task of insuring that systems are portrayed accurately by historical, current, and future price and cost relationships becomes more difficult.

Many examples of investigations in this phase of methodologies could be listed. Some focus primarily on evaluating forage production systems, while others concentrate on cow/calf and stocker production systems. Still others bring the pasture production and livestock utilization together into integrated systems. The following citations are provided to illustrate some problems economists might face in analysis of results and to suggest how results, conclusions, and implications could be enhanced with the application of economic principles.

Mooso et al. (1990) investigated several methods for producing winter pasture to graze stockers. Authors included a basic costs and returns analysis to arrive at net returns per acre for the various systems. However, their analysis did not accurately depict individually the economic benefits of each production system as gross returns were calculated using average results. Conclusions based on such narrowly defined results have limited application to producers who face rapidly changing economic conditions. More informative economic conclusions would result from comparing systems on their individual merits. Sensitivity analysis would then suggest changes expected with variations in inputs and prices.

Evers (1989) included an estimate of costs on a per pound of calf produced basis for several pasture production systems being evaluated. However, differences in calving rates were not included and would have significantly affected economic comparisons of alternative systems.

Studies such as these two provide valuable information about production parameters which would be appropriate when incorporated into larger systems models. Results from such studies are more valuable for management decision making once they are combined with weather and soil data, market conditions, livestock characteristics, and other important relationships.

Complexity introduced by the many interrelationships characteristic of integrated pasture/forage and livestock systems quickly becomes evident as researchers investigate production and economic issues. Results of recent studies by Knight et al. (1990) and Gaertner (1991) illustrate difficulties of evaluating the efficiency of production systems which include both forage and livestock components.

Knight et al. (1990) provided guidelines for beef cattle producers to select grazing system, stocking rate, and supplementation practices on rangelands. Grazing systems and winter supplementation programs were evaluated based exclusively on production performance measures.

Gaertner (1991) analyzed cow herd performance data to evaluate the influence of grazing pressure on forage attributes and animal performance in East Texas. Results indicated that interactions between grazing systems, stocking rates, and the inherent genetic potential of calves markedly influenced their preweaning performance.

Both of these studies provide timely, useful information which managers can apply directly to a variety of production situations. However, results would be much more meaningful if additional economic implications were included.

Results from Gaertner (1991) provided a basis for estimating differences in costs of production and net returns for pasture/livestock systems utilizing Fall, Winter, and Spring calving strategies. Revenues minus operating costs were $67 and $46 per head more for Fall and Winter calves, respectively, than for Spring calves given the set of as-

sumptions used. Breakeven prices to cover operating costs included in the analysis were $44.24, $50.59, and $56.36 per cwt. for Fall, Winter, and Spring calves, respectively. Ownership costs and returns to other factors of production were similar across alternatives and were not included in comparisons.

A major problem confronting agronomists and others involved in forage research is the difficulty in placing economic values on new practices since forages generally are marketed through livestock. For example, what is the economic advantage of doubling clover seeding rates if this practice increases early forage production by 40 percent? A model of this system may be appropriate to illustrate economic advantages whether they result from less hay needed, earlier calving dates, or higher conception rates.

Many forage-livestock systems that are evaluated and recommended based on production performance have little application for commercial farmers and ranchers once current costs and returns are estimated. Furthermore, the next logical step beyond just comparing systems as unique opportunities is to aggregate alternatives into models to estimate cost minimizing or profit maximizing strategies.

It is important to remember that optimal strategies are not always compatible with management goals and thus are not alternatives considered desirable by owners or managers. This is why it is critical that results generated by hard systems models be further evaluated in the context of human activity systems under which they are generated.

Investigations Involving Applied Science or Technology Development

Applied science methodologies converge on problems that are components of larger more complex systems. Reductionism, repeatability, and refutation are expected from applied science as they are from basic science. Typical objectives include optimizing factors under investigation similar to hard systems.

The technology development approach to agricultural problems tackles questions like "What new thing and/or process can be created or redesigned to meet the requirements of this particular situation?" With this in mind, the following citations are presented as examples of applied science/technology development in forage-livestock systems.

Growth and development of heifers is a critical element of cow/calf systems. Decisions concerning reproduction and replacement strategies depend on the effectiveness of preparing heifers for breeding herds. Rouquette et al. (1990b) evaluated growth and development of F-1 heifers under various short-term grazing pressures. Even though an economic analysis was not presented, results could be utilized directly in models evaluating cow replacement strategies based on accepted asset replacement principles.

It has been argued that technologies recommended as low-input sustainable agriculture (LISA) systems are not new, but are old basic farm management concepts being revisited. Whether this is true or not, economic evaluation of changes in existing production practices often calls for partial budget analysis.

Rouquette et al. (1990a) evaluated alternative winter pasture fertilization methods to determine the influence of nitrogen source on performance of animals and pasture. Fertilizer, seed, and planting costs were aggregated to estimate cost per pound of gain as a measure of economic efficiency to compare systems. Such an approach demonstrated main differences in costs, however a complete partial budget would have allowed for a more detailed accounting of costs and would have captured marketing benefits and costs associated with selling different weight animals.

Supplemental protein fed free-choice and with self-limiters to cattle on bermudagrass pasture was evaluated by Grigsby et al. (1988 a and b). Performance data were provided and showed dramatic improvements in average daily gains and other performance measures. The economic impact of improvements was not estimated even though results clearly were well adapted to basic economic analysis. Costs of implementing supplemental feeding programs and returns from added livestock gains could easily have been estimated and reported.

A similar study by Rouquette et al. (1990c) determined the influence of two levels of corn-based supplemental feed rations on intake and daily gain for calves grazing rye-ryegrass pastures. Results have significant implications for producers attempting to identify and adopt production practices that improve profitability. Producers have insufficient information to make such decisions unless economic implications accompany productivity results.

Down to the Basics

Basic science inquiry proceeds by analyzing problems that initiate inquiry, conceptually reducing them to a systematic collection of facts that are initially thought to be relevant, and creating hypotheses suggested by relevant facts. Hypotheses are tested experimentally several times, and the competing hypotheses refuted (Wilson and Morren, Jr., 1990).

This lowest level of the holistic integration-reduction spiral relies on reducing problems to testable proportions, experimentally testing resulting hypotheses quantitatively, and reducing as many variables as possible. Results of problems addressed at this level explain cause and effect or how basic components interact. Much of the time basic research involves crop or livestock responses to changes in specific inputs.

Examples from an extensive list of forage-based research classified as basic are Leonard (1986), Hillard (1989), and Thom et al. (1990). Basic research involving livestock generally addresses problems in nutrition, reproduction, and production where issues are reduced to single quantifiable relationships. Combining basic systems into operations moves one up to the applied level addressed previously.

Clary et al. (1990) provides sample applications of economic principles to basic research results. Three basic economic principles focussing on marginal costs and returns are explained and applied to results of several research projects to illustrate how decisions about levels of resource use should be made.

Production functions of two or more variables create complexity when applying economics to production surfaces. It is necessary to hold all other input use levels constant in order to estimate the optimal use level of a selected input. Estimates of net returns to a group of selected provides an approximation of the profit maximizing combination of these resources which should be used in production.

Summary

Experience has shown that there likely are thousands of files filled with important research findings which have never been subjected to even basic farm-level economic analysis. More often now than in the past, scientists recognize the integral role input costs and market prices play on the rate of technology adoption, on the proper use of resources for production, and on decisions about which enterprises will be most profitable.

No one person, group, or discipline should be blamed for the lack of emphasis on application of economics to production relationships. It could be argued that the "system" is to blame since there often is little reward and extra stress associated with true collaborative or interdisciplinary efforts. Only recently many peer reviewed journals have begun to encourage articles combining production and economic results.

A case also could be made that economists most interested in the application of economic principles to production issues as outlined here are primarily Extension specialists. Specialists' interest in issues often results from addressing producer questions, concerns, and suggestions that arise while assisting managers of farms and ranches.

Producers can no longer afford to manage farms and ranches with maximum production as their primary goal. Maximum efficiency of production can result only from matching costs of production and market prices with sound production practices based on solid well-tested research results.

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COST-BENEFIT COMPARISONS OF INFECTED FESCUE AND SELECTED ALTERNATIVES

Lynn Harwell

In 1987, economist J.E. Standaert at North Carolina State University published a report on the costs and benefits of renewing fescue pastures (Standaert 1987). Dr. Standaert's efforts were among the first trying to deal with the economics of this very perplexing fescue endophyte problem.

Although the problem-solving model developed in the Standaert report did help address the issue in those days when we knew so little, perhaps the most value came from the unanswered questions raised by the study. The questions fell into two categories. First came those questions best answered by researchers in agronomy and animal science. The needed information involved the fungus relation to:

Agronomy	Animal Science
Plant persistance	Milk production
Plant yield	Calf and stocker gains
Grass-legume dilutions	Cow condition
Sward density	Cow fertility
Length and time of grazing	Animal intake
Stocking rates	Withdrawal times

The second group of unanswered questions concerned items we can get only from a particular farm. This information is grouped under the general heading "farm situation", and includes, at a minimum, the following:

Degree of infestation
Sward composition
Grazing management
Animal enterprize
Pasture makeup
Soil(s) type

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Farmers exercise management control over their resources in a multitude of ways. For the sake of convenience we often group resource condition or use into categories.

For example, the degree of fungus infestation may vary from zero to 100 percent, but perhaps it can be divided into 5 categories of 20 percent each. Let's say we make divisions for sward composition (warm and/or cool season, legumes, etc.) for three categories. Grazing management is again of infinite variety, but perhaps we can say it is either continuous, rotational, or intensive, for a total of three categories. Animal enterprize (purebred, cow-calf and/or stocker) consumes three categories, and pasture makeup (size, slope, aspect) and soils another six categories.

Even if we know with some assurance all fungus effects on cattle and grass, which we do not as yet, and with these very simplistic assumptions about management, we face a total of 810 combinations (5 x 3 x 3 x 3 x 6 = 810) and we still haven't said anything about supplemental feeding practices! How can we make a fescue management decision without getting bogged down in numbers?

USING A PARTIAL BUDGET

In partial budgeting, we do not concern ourselves with the total farm operation, or even with all aspects of a given farm enterprise. We are interested in only those things in which we contemplate a change.

Say we wish to consider using an existing feed mill to grind the ration for some replacements we plan to sell, rather than continue to have feed delivered by a dealer. We begin by looking at the effects the proposed change will make on our profit picture.

The anticipated change from using home grown rather than purchased feed can affect profits through changes in either costs or revenues. If revenues go up (selling feed to others) or costs go down

(buy less feed), we are better off. If costs go up (fuel to power the mill) or revenues go down (will have less grain for sale), we are worse off.

The types of effects described above are all we need to consider. We can obtain a net difference and apply it to our existing profit or loss figure. It is only the net difference we are after as we use partial budgeting to consider the change.

For practical use, we can apply that adjustment to the records Farmer A keeps on his farm, or Farmer B's, or whomever. Of course, they will want to make sure that the adjustments we make are consistent with their particular situation, but they won't have to reconstruct their entire farm's operating accounts to do it. And we are not caught in the trap of assuming away all reality in order to design a scheme to fit 810 (or more) management situations.

A Cow-calf Example

A typical South Carolina Piedmont cow-calf budget, in summary form, looks like this (Harwell 1990):

Item	Per Head
Gross Returns	$ 349.79
Variable Costs	192.67
Gross Margin (returns above variable costs)	$ 157.12
Fixed Costs	$ 109.80
Overhead Costs	15.41
Land Costs	29.00
Returns to Management and Risk	$ 2.91

We are not concerned here with the bottom line. Even so, the budget clearly indicates that even at today's strong prices, when all costs including labor are accounted for, a 75 percent calf crop will provide little more than a breakeven proposition! The assumptions peculiar to the unique situation this budget represents, look like this:

Herd size	100
Cull cow weight	950.0
No. acres	200
No. steers sold	37.5
Percent calf crop	75
No. heifers sold	20.5
Average calf weight	502
No. culls sold	15.0
Steer prices ($/cwt)	97
Heifer prices ($/cwt)	87
Cow prices ($/cwt)	52
Calf age (days)	205

We also assume the level of infestation from the endophyte to be 60%.

How much will this profit figure be affected if we replant the fescue pasture with a fungus free variety? Using the partial budgeting technique, we need to know 1) which adjustments to the budget will increase our profits, either through increased returns or decreased costs, and 2) which changes will decrease our profits because of either decreased returns or increased costs.

Considering positive effects on cow-calf profits, Schmidt at Alabama has compiled research available from animal scientists in five states (Schmidt 1990). The research compared performance from animals grazing high endophyte (> 90%) with low (< 5%) endophyte fescue. Average results show:

1) Calf weights (205 day) will be higher by .3 lbs/day.
2) Cow weights will rise by .5 lbs per day during nursing period.
3) Calf crop will improve by about 20 percentage points.

We use this information to adjust the profit figure in the budget above. Since the level of infestation assumed in the budget is 60%, we will increase the daily gains on calves by only .1 lbs/day, the daily gains on cows by .3 lbs/day, and raise the calving percentage by 15 points to 90%. Then:

Increased revenues from steers (205 x .1 x $ .97 x 37.5)	$ 745.69
Increased revenues from heifers (205 x .1 x $ .87 x 20.5)	365.62
Increased revenues from cull cows (205 x .3 x $ .52 x 15)	479.70
Increased calving % - steers (545 x $ .97 x 7.5)	3964.88
Increased calving % - heifers (495 x $ .87 x 7.5)	3229.88
Total	$8785.77
Total increased revenue per cow	87.85
Total increased revenue per acre (2 ac/cow)	43.93

NOTE: This increased revenue does not end after one year, but could reasonably be expected to run on into the future. Some agronomists use seven years as the average effective life of a fescue stand.

Now we must look for the negative effects on profits. There are two: 1) the cost of establishing the pasture, and 2) decreased forage production caused by having to rest the new pasture though part of the first year. Again, we need a budget, this time a forage budget for reestablishing fescue-clover. This one's from Clemson (Harwell et al. 1989):

Variable costs	
Fescue seed (15 lbs @ $1.20)	$ 18.00
Clover seed (3 lbs @ $3.50)	9.00
Oat seed (1.5 bu @ $3.50)	5.25
Paraquat (2 pts @ $8.00)	16.00
Machinery, equipment	7.63
Labor	5.31
Interest on operating capital	3.06
	$ 64.25
Fixed costs	
Machinery, equipment	$ 10.47
Overhead (8% of variable costs)	5.14
	15.17
Total Costs	$ 79.86

It is assumed that pasture production in the first year will be reduced by 40%. We determined above that the additional value from endophyte-free fescue is $43.93 per acre. Forty percent of that figure is $17.57 per acre.

Therefore, the total negative effect on profits is:

Cost of reestablishment	$ 79.86
From lost grazing	$ 17.57
	$ 97.43

How does one compare annual gains of $43.93 per acre with one-time costs which run $ 97.43 per acre? One method is to use the payback approach. In this case, the costs of the new pasture would be paid back in a little over two years (97.43 / 43.93 = 2.22 years).

The present value method, explained in any financial textbook, gives more realistic answers when analyzing numbers running several years into the future (Hopkin et al. 1973; Lee et al. 1980). Tables of present value factors available in such texts make calculations simple. Present values convert future revenues or costs into amounts that can be compared directly with amounts being received or spent in the present.

If it is expected that the stand is to last seven years and that a 10 percent interest rate is appropriate, then the annual return of $43.93 for seven years can be multiplied by the appropriate

present value factor (4.868) to obtain a present value of $213.86. This amount can then be compared directly with one-time costs of $97.43. The net benefit from the fungus free fescue is thus $213.86 - $97.43 = $116.43 per acre. Clearly, the investment is profitable using either the payback or net present value approach.

The Endophyte and Stocker Cattle

A recent Auburn University budget shows returns to land, labor, and management for 350 lb steers on fescue pasture of $49.52 per head (Crews 1989). They are run for 200 days at 1.25 head per acre. Per acre returns would thus be $49.52 x 1.25 = $61.90. The animals are heavily supplemented with hay, grain, and protein (total cost = $15.30/hd) and are expected to gain 1.75 lbs/day.

Alabama fescue establishment costs (less fertilizer) total $62.08 per acre. In a partial budgeting approach we ignore the fertilizer because it would be used even if we had retained the old pasture. To cover reduced pasturage the first year, we add in 40 percent of the anticipated returns ($61.90 x .4 = $24.76) for a total establishment cost of $ 86.84 per acre ($62.08 + $24.76 = $86.84).

If those Alabama steers would gain an extra .1 pound per day on fungus free fescue, and we could save one-half the $15.30 supplementation expense, our partial budget would look like this:

Positive additions:

Additional annual revenue per animal
(200 days x .1 lbs x $.92)
$18.40

Additional revenue per acre
($18.40 x 1.25) $23.00

Reduced annual feed cost per animal
($15.30/hd x .5) $ 7.65

Reduced costs per acre
($7.65 x 1.25) 9.56

Total Positive Effect per acre
on Profits
(annual) $32.56

Negative additions:

Additional cost per acre 86.84

Total Negative Effect
on Profits (one-time basis) $86.84

PAYBACK APPROACH
($86.84 / $32.56) = 2.67 years

PRESENT VALUE APPROACH
PV of $32.56 at 10% for 7 years
(4.868) = $158.50

Then compare $158.50 benefit with
$86.84 detriment

Net Effect on Profits
$158.50 - $86.84 = $71.66 per acre

The endophyte fescue investment looks less profitable here, although it is still attractive. Of course, it is only being used for 200 days per year in this example. If hay or additional grazing could be obtained during other parts of the year, profits could be enhanced.

Interseeding Clover into an Infected Stand

Cattle performance research on the effect of interseeding clover into infected stands of fescue is underway. The partial budgeting approach will again give needed information for making management decisions.

In a quick and dirty example, if we saved fescue seed, oat seed, paraquat, and one-half the machinery costs (for a total savings of $48.30) from the fescue re-establishment budget given earlier above, our one time investment would be reduced from $97.43 to $49.13. We will assume that the interseeded fescue gives gains and condition equal to non-infected fescue.

In the cow-calf example, paybacks would be reduced from 2.22 years to 1.12 years. The present value decision then becomes one of comparing an income stream worth $213.86 with a one time investment of $49.13, for a net investment benefit of $164.73 per acre.

INTERACTIVE BUDGETS

Another approach to avoiding the numbers avalanche takes advantage of emerging portable computer capability and involves the use of spreadsheet compilers. These technologies allow us to formulate an interactive budget which can be operated on a laptop computer at any remote location where electric service is available.

One example of a spreadsheet compiler is a software program marketed under the tradename BALER (Brubaker & Associates, Inc. 1988). Using this software, a budget developed on a spreadsheet such as LOTUS 1-2-3 can be made to run independently. No knowledge of the parent spreadsheet program is required. The "baled" version of the budget can be placed on a floppy disk and run on any personal computer with a modest storage capability.

The "baled" version of the budget can be manipulated, with some limitations. Quantitative assumptions, prices, and numerical coefficients related to tons, acres, gallons, etc., can be readily changed and a new budget calculated almost instantly. Only the general format and the internal equations used to calculate the extensions must remain intact.

CONCLUSIONS

Management decisions made to deal with the fescue endophyte problem can be made easier in looking at partial budgets. We reduce the volume of numbers we handle and the answers derived fit a rather large number of situations.

Additional research from physical scientists continues to become available. Information pertaining to specific on-farm situations can now be more readily accommodated through the use of interactive budgets. Unfortunately, agronomists, animal scientists, and economists direct too little research toward farming systems. It is a system which any farmer must learn to operate. The fescue endophyte problem causes monumental losses each year in the Southeast. An understanding of the costs and benefits involved will be of major benefit to the regions' agricultural economy.

The most important question is: Will fescue reestablishment pay on my farm? For some cost-conscious exceptional managers, a rather light 30% infection may be too much to tolerate. For others, particularly those with off-farm obli-ations and lower levels of management, a 90% infection level may have to be tolerated.

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PRODUCTION PERFORMANCE AND ECONOMIC ANALYSES OF SELECTED SOUTHERN FORAGES AS PASTURE FOR STOCKER STEERS

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INTRODUCTION

In most livestock operations in the Southeast, the primary factor limiting production is nutrition. Animal breeding and animal genetics are of great importance and receive much emphasis, but on most farms the existing genetic potential of livestock is never fully realized due to insufficient levels of nutrition, especially energy.

Most producers know, or can easily determine, what forage species and varieties are best adapted on land they have available for pasture. In addition, once they have decided the type of livestock enterprise and the forage species they will use, producers can normally obtain good advice regarding animal management or pasture management practices.

However, selection of the best forage species to use from among several which are adopted is a critically important managerial decision. It requires a basic understanding of the relative usefulness of those forages with regard to providing nutrition for grazing animals and, ultimately, to achieving acceptable profits with reasonable risk.

COMPARISON OF SELECTED SOUTHERN FORAGE SPECIES

Auburn University scientists have conducted many grazing experiments involving steers. A number of these studies involved animals of generally similar breeding and weights and were conducted over multiple years. Thus, they provide a good basis for comparison of the animal production potential, and the profit potential, of various commonly used forage species.

An early test at the Wiregrass Substation (WG) near Headland evaluated steer performance at four nitrogen levels on 'Coastal' bermudagrass (Cynodon dactylon L.), and at three levels on both 'Pensacola' bahiagrass (Paspalum notatum Flugge) and "common" bermudagrass (Hoveland, et. al., 1960). A later study (Harris, et al., 1972) at the Tennessee Valley Substation (TVS) near Belle Mina compared bermudagrass interseeded with either hairy vetch (Vicia villosa Roth) or 'Explorer' rye (Secale cereale L.).

At the Black Belt Substation (BBS) near Marion Junction, the tall fescue (Festuca arundinacea Schreb.) varieties 'AU Triumph' (0% fungal endophyte) and 'Kentucky 31' tall fescue (having either 1, 34, or 90% endophyte) were compared in-one study (Pedersen et al., 1987), and Kentucky 31 having <5% endophyte or 94% endophyte were tested in another (Hoveland, et al., 1984). Also at that

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station, highly endophyte-infected Kentucky 31 fescue and AP-2, an experimental line of hardinggrass (Phalaris aquatica L.), were evaluated (Hoveland et al., 1979).

Highly endophyte-infected tall fescue was also grazed in pure stands as well as with either ladino clover (Trifolium repens L.) or birdsfoot trefoil (Lotus corniculatus L.) at the

Sand Mountain Substation (SMS) near Crossville (Hoveland et al., 1981). In other work with cool season perennials at the Tennessee Valley Substation, steer gains on orchardgrass (Dactylis glomerata L.)/ladino clover were obtained in one test (Harris et al., 1984), and on Kentucky 31 tall fescue and common orchardgrass, both grown with and without Regal white clover, in another (Harris et al., 1972).

Continuously grazed AU Lotan' sericea lespedeza (Lespedeza cuneata (Dumont) G. Don) was tested against rotationally grazed AU Lotan, Serala' sericea, and Cimmarron' alfalfa (Medicago sativa L.) at the Upper Coastal Plain Substation (UCP) near Winfield (Schmidt,1987). In other work, Funk's 78F' sorghum/sudan (Sorghum bicolor Moench.) was evaluated at the Tennessee Valley Substation (Hoveland et al., 1971), and various winter annual mixtures including rye, oats (Avena sativa L.), ryegrass (Lolium multiflorum Lam.), and crimson clover (Trifolium incarnatum L.) were tested at the Lower Coastal Plain Substation (LCP) near Camden (Harris et. al., 1971).

A summary of performance criteria for stocker steers grazing the 37 treatments used in these Auburn University grazing studies is provided in Table 1 (further reference to these treatments will be either by name or treatment number as provided in Table 1). In addition, the 1990 Auburn University budgets for the various forage species or species mixtures involved in these studies were used to calculate the approximate pasture costs per acre as well as the pasture costs per pound of gain, Table 2.

FORAGE PERFORMANCE AND COST OF GAIN

As expected, the performance criteria reported in these experiments varied greatly among the various pasture species. The number of calendar grazing days ranged from a low of 77 for sorghum/sudan (13) at the TVS to a high of 238 for an orchardgrass/white clover mixture (29) at the same location.

The variation in calendar grazing days was greater among cool season species and mixtures than among warm season pastures. Presumably this is because in Alabama both severe cold in winter and extreme heat and drought in summer can greatly reduce cool season forage growth in some years, while warm season species are somewhat less likely to be affected by climatic conditions.

In the small number of treatments considered in this exercise, endophyte status did not affect the number of grazing days. Also, the presence of a legume companion species did not greatly affect the number of grazing days.

The best average daily gains (1.8 lbs or higher) and gains/steer (300 lbs or higher) were obtained with alfalfa (14), endophyte-free tall fescue (18,19,22), orchardgrass with white clover (29), and low tannin sericea (17). Lowest average daily gain occurred with sorghum-sudan (13).

Gain per acre was best on highly nitrogen-fertilized Coastal bermudagrass (3, 4), bermudagrass overseeded with rye or hairy vetch (11, 12), an infected fescue/ white clover mixture (32), an orchardgrass/white clover mixture (29), endophyte-free fescue (18), and winter annuals (34, 35) . The lowest gains/acre were obtained on common bermudagrass receiving no nitrogen fertilizer, and on sorghum-sudan.

The calculated pasture cost figures provide some particularly interesting comparisons. For example, Coastal bermudagrass and bahiagrass were similar at all levels of nitrogen fertilization, but both were lower than common bermudagrass. Pasture cost/pound of gain for sorghum-sudan ($0.46) was considerably higher than for any warm season perennial grass treatment.

Although animal gain figures for alfalfa are impressive, pasture cost/pound of gain for this species ($0.25) is higher than other top-producing forages. By contrast, although animal gains on sericea lespedeza are much less, pasture cost/pound of gain is quite low ($0.15-$0.18).

With tall fescue, pasture cost was inversely proportional to the level of endophyte infection, ranging from $0.22 to $0.27 for endophyte-free fescue to a range of $0.27-$0.43 for highly infected fescue. However, when clover was present with infected fescue, the pasture cost per pound of gain figures were $0.10-$0.25, as good or better than non-infected fescue.

There can be great variations in profit potential even in similar types of pasture systems. An illustration would be infested fescue with white clover. One of the two treatments (32), was one of the top performers and had the lowest cost ($0.10) of all 37 treatments. Conversely, the other treatment (30) was rated among the lowest performers and a cost of gain of $0.25 . Likewise, with an improved orchardgrass variety grown with white clover (29), the pasture cost per pound of gain was $0.12 (second lowest of the 37 treatments), while in another experiment at the same location it was $0.25 for common orchardgrass/white clover (31) and $0.50 (highest of all treatments) for common orchardgrass (25) alone.

Overall, the lowest pasture costs per pound of gain were obtained with tall fescue/white clover at the SMS (10 cents), orchardgrass/white clover at the TVS (12 cents), and with sericea lespedeza at the UCP (15 to 18 cents). The highest costs/pound of gain occurred with common bermudagrass receiving no nitrogen (WG), sorghum-sudan (TVS), common orchardgrass, highly infected fescue and alfalfa; all with costs above 40 cents.

When animal and other costs of production are included, total cost of gain figures follow a similar pattern, with a few noted exceptions (Table 3). The forages having a "low" total cost of gain (less

than 50 cents per pound) were basically those for which pasture costs alone were lowest. The "high" total cost of gain forages (greater than 75 cents per pound) were sorghum/sudan, common bermudagrasses, highly infected fescue, common orchardgrass and highly infected tall fescue/white clover (30). A notable exception is alfalfa, which fell into the high cost category when looking at pasture costs alone, but with regard to total costs only falls in the moderate range. These differences, compared to pasture costs alone, are due mainly to stocking rates and associated per head costs such as veterinary and medication, supplemental feed and interest on operating capital.

ECONOMIC EFFICIENCY AND RISK

Production efficiency criteria such as average daily gain, stocking rate and total gain per acre are all critical factors that ultimately influence economic efficiency, i.e. profits. However, if maximization of returns (profits) is the primary objective, value of output must be considered.

Cost of gain is a highly important economic measure as has been discussed. To arrive at a profit estimate, whether on a "per acre" or a "per head" basis, the value of gain must be considered. Value of gain and cost of gain are similar in that both are based on the "gain or output added" to the unit of production. The value of gain is calculated by subtracting the purchase value from the selling value and then dividing by the total amount of gain. The value of gain concept is important in emphasizing differences in price levels of output (e.g. stocker steers).

The approach taken to incorporate risk into this analysis is to evaluate both production and price variability. Production variability is in terms of gain per acre. To determine this measure, the dependent variable (gain/acre) was regressed on the independent variables of stocking rate, grazing days, and nitrogen rates, where applicable. From that, the mean and deviation (standard) was set in a uniform distribution format.

Price variability was derived by looking at both purchase and selling price data over a ten year period for the appropriate weight categories and time of the year the respective forage types would allow placement on and removal of animals from, grazing. This approach also reflects seasonal pricing patterns depending on when purchases and sales are expected to occur. Price variations were constructed in a histogram format by their probability of occurrence over a ten year period and time of the year animals would have been purchased or sold. Price differentials were included to reflect ending weight differences (Beginning weights were assumed to be 500 pounds across all treatments.)

Simulations to calculate profitability measures were performed using @RISK (TM). This is a "utility" program that attaches to LOTUS-123 (TM). Five hundred iterations were run to capture the risk and impact from the stochastic nature of "gain/acre" and "purchase/selling prices". Output from the @RISK program gave a cumulative measure of the "expected profits", "degree of variability" and "probability of positive returns" for the various forage types and species. This allows for economic comparisons between and among forage groups.

PROBABILITY OF POSITIVE RETURNS

By simulating the various potential (stochastic) outcomes over 500 iterations (Table 4), the "Mean Returns" represents a single, composite estimate regarding profitability. A wide range of mean returns are reflected, varying from a low of $231.59 per acre above total costs for sorghum/sudan to a profit of $155.28 for tall fescue/clover (32). Perhaps a better aggregate measure of variability and risk among forage types and species is the calculation of the "Probability of Positive Returns".

The probability of "returns above total costs per acre" are greatest (> 50%) for endophyte-free fescues, 2 of the 3 tall fescue/clover treatments, 1 of 2 orchardgrass/clover treatments, coastal bermudagrass/vetch, low tannin sericia, and 3 of the 4 winter annual treatments. On the opposite end of the spectrum, treatments with the lowest probability (< twenty-five %) were common bermudagrass (0# nitrogen), sorghum/sudan and the highly infected fescue.

OPPORTUNITIES

These analyses provide interesting comparisons. A producer's decision as to what forage species to use can be affected by many factors including soil types, available capital, available labor, and past success with various species. However, when our region as a whole is considered, this data indicates that several of the forage species included offer opportunity as compared to other commonly used species.

For example, animal performance and the potential for profit is great with endophyte-free tall fescue. However, enthusiasm for this option must be tempered with the knowledge that endophyte-free tall fescue has been shown to be generally less stress tolerant than infected fescue. Therefore, endophyte-free tall fescue offers an opportunity only under good management levels and in areas in which tall fescue is well adapted.

This data also indicates that producers who have infected tall fescue have a tool at their disposal which can offset the gain- and profit-suppressing effects of endophyte infection. By interseeding white clover or other legumes, the adverse effects on animal gains and pasture costs can be largely offset. Likewise, an orchardgrass-legume mixture can be quite economically attractive.

All measures of animal gain on alfalfa are impressively high, although the cost of production is also high relative to other grazing crops. Some grazing test with alfalfa (in other Southern States) have shown production levels higher than achieved in the example used in this exercise. When producers have suitable soil, when they see an opportunity for profit associated with rapid animal gains, and if they are willing to exercise the management alfalfa requires, alfalfa could be an attractive option.

Among warm season perennial grasses, hybrid bermudagrass appeared most economically attractive in this exercise. The strong point of bermudagrass is a potentially high stocking rate and gain/acre under high levels of nitrogen fertilization. Thus, when land available for production is a limiting factor, or when nitrogen sources are available at low cost, bermudagrass may be a good

choice. Overseeding with winter annuals, especially a winter annual legume, increases the probability of profits.

Perhaps surprisingly to some people, sericea lespedeza seems to also constitute an opportunity on many livestock farms. This widely adapted forage legume does not provide spectacular animal performance, and it has the disadvantages of having rather poor seedling vigor and requiring management to avoid overgrazing, but is attractive from the standpoint of low-cost summer animal production. The opportunity with this species is primarily on poorer soils.

Finally, winter annuals provide a long growing season and excellent animal performance. Although multiple-year establishment costs are higher than with perennials, the economics of using winter annuals, especially for animals having relatively high nutritional requirements, are quite attractive.

SUMMARY

There is value associated with having a basic knowledge of the extent to which various types of pastures may affect animal performance criteria. This exercise provides prima facie evidence that there is great variation among, commonly-used Southern-adapted forage species with regard to the animal performance criteria commonly used to evaluate forage/livestock systems. Furthermore, input costs and seasonality of purchase/selling prices of animals vary as well.

There does seem to be evidence that the length of grazing is closely correlated to profit potential. This is understandable because once a commitment is made, whether for fertilizer or number of animals stocked, they become fixed factors of production and being able to spread these costs over a longer period, i.e. more pounds per acre; reduces per unit cost and enhances profit potential. Addition of legumes also increase the chances of profits by improving animal performance and reduction in the reliance and cost of nitrogen.

While nominal (actual) seasonality of price fluctuations seem to give a subtle advantage (buy/sell margins) to the cool-season based forages, this edge becomes neutralized when evaluation is made using "deflated" prices.

Based on this study, indication is that maximizing gain per acre is not necessarily correlated with profit maximization. This relates to marginal cost/marginal return concepts and discussions regarding "biological vs. economic" optimums. Maximizing biological output is a very important factor in terms of production efficiency. If inputs were free, then the biological optimum would also be the economic optimum, given output prices were the same. However, in a realistic sense, inputs do have a cost and that is why consideration must be given to output value and achieving the production level where the difference between per unit costs and per unit returns (value) is greatest. The intent of this paper is was to derive the optimum stocking rate, gain per acre, etc., but rather to introduce "risk" as a comparative measure in evaluating the various forage systems and what influence they have on profitability.

Clearly, there is great complexity involved in evaluating the relative feasibility of various forage species or mixtures as grazing crops for profitable beef production. In addition to determining what forages are adapted, producers must carefully assess marketing strategies, expenses associated with owning animals, as well as labor, available capital, financial position, and other resources associated with the demands and overall risk of the production system used. Varying managerial capabilities can go far in explaining the degree of variability inherent to all of the treatments analyzed, thus, while some trends are evident, the production approach which is best for a particular individual, must be determined on a case-by-case basis.

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Table 1. Production performance data for stocker steers utilizing various forage types and varieties.

Item Description	Item No.	Pasture	Line or Variety	Calendar Days Grazing	Nitrogen Rate	Stocking Rate	Average Daily Gain	Total Gain	Years of Data
					#/ac./yr	hd./ac.	#/hd.	#/ac.	
WARM SEASON PERENNIAL GRASSES	1	Bermudagrass	Coastal	168	0	1.40	NS(4)	250	4
	2	Bermudagrass	Coastal	168	80	1.70	NS	340	4
	3	Bermudagrass	Coastal	168	160	2.60	NS	480	4
	4	Bermudagrass	Coastal	168	320	3.50	NS	620	4
	5	Bahiagrass	Pensacola	168	0	1.20	NS	220	3
	6	Bahiagrass	Pensacola	168	80	1.80	NS	290	3
	7	Bahiagrass	Pensacola	168	160	2.00	NS	350	3
	8	Bermudagrass	Common	168	0	0.70	NS	100	3
	9	Bermudagrass	Common	168	80	1.40	NS	230	3
	10	Bermudagrass	Common	168	160	1.80	NS	300	3
WARM PERENNIALS W/WINTER ANNUALS	11	Bermudagrass w/ Vetch	Coastal/Hairy	161	0	2.26	1.29	493	8
	12	Bermudagrass w/ Rye	Coastal/Explorer	161	150	2.45	1.30	530	8
SUMMER ANNUALS	13	Sorghum/Sudan	Funks 78-F	77	100	2.80	1.10	210	3
WARM SEASON PERENNIAL LEGUMES	14	Alfalfa	Cimarron	163	0	1.30	2.16	475	3
	15	Sericia Lezpedeza(2)	Serala	139	0	1.30	1.39	248	3
	16	Sericia Lezpecleza(2)	AU Lotan	139	0	1.20	1.65	276	3
	17	Sericia Lezpedeza	AU Lotan	139	0	1.20	1.87	306	3
COOL SEASON PERENNIAL GRASSES	18	Tall Fescue(3)	AU Triumph (0%)	170	200	1.54	2.09	519	3
	19	Tall Fescue	KY 31 (1%)	170	200	1.32	2.16	462	3
	20	Tall Fescue	KY 31 (34%)	170	200	1.40	1.76	397	3
	21	Tall Fescue	KY 31 (90%)	170	200	1.77	1.41	370	3
	22	Tall Fescue	KY 31 (<5%)	172	200	1.32	1.82	426	4
	23	Tall Fescue	KY 31 (94%)	172	200	1.73	1.00	301	4
	24	Tall Fescue	KY 31 (High%)	150	150	2.13	1.31	268	8
	25	Orchardgrass	Common	139	150	1.27	1.77	200	8
	26	Tall Fescue	KY 31 (0%)	177	200	1.40	1.78	434	3
	27	Hardinggrass	AP-2	177	200	1.26	1.73	347	3
	28	Tall Fescue	KY 31	206	150	1.76	1.06	374	2
COOL SEASON PERENNIAL GRASSES W/ LEGUMES	29	Orchardgrass w/ Ladino	Hallmark/Regal	238	0	1.97	1.62	505	2
	30	Tall Fescue w/ Ladino	KY 31/Regal	143	0	1.81	1.46	244	8
	31	Orchardgrass w/ Ladino	Common/Regal	143	0	1.46	1.83	244	8
	32	Tall Fescue w/ Ladino	KY 31/Regal	205	0	1.63	1.53	582	2
	33	Tall Fescue w/ Birdsfoot	KY 31/Fergus	194	0	1.24	1.51	398	2
WINTER ANNUAL GRASSES	34	Rye, Oats & Crim. Clover	NS(3)	121	130	2.00	1.37	544	2
	35	Rye & Ryegrass	NS	153	130	1.86	1.36	528	7
	36	Rye, Ryegrass & Crimson	NS	177	130	1.31	1.57	364	6
	37	Oats & Crimson Clover	NS	201	130	1.38	1.60	443	2

(1) Data compiled from a series of Experiment Station reports (see references). Majority of steers were crossbred with an initial weight of approximately 500 pounds.
(2) Rotationally grazed.
(3) Fescue varieties where indicated are identified by percentage of endophyte infestation.
(4) NS = Not Specified.

Table 2. Estimated cost of gain (pasture only) for stocker steers utilizing various forage types and varieties.

Item No.	Pasture	Line or Variety	Total Gain	Pasture(1) Costs (Variable)	Pasture(2) Costs (Total)	Cost of Gain (Variable)	Cost of Gain (Total)
			#/ac.	$/ac.	$/ac.	$/cwt	$/cwt
1	Bermudagrass	Coastal	250	26.29	50.69	10.52	20.28
2	Bermudagrass	Coastal	340	49.18	75.19	14.46	22.11
3	Bermudagrass	Coastal	480	72.08	99.69	15.02	20.77
4	Bermudagrass	Coastal	620	117.87	148.68	19.01	23.98
5	Bahiagrass	Pensacola	220	26.26	45.66	11.95	20.75
6	Bahiagrass	Pensacola	290	49.18	70.16	16.96	24.19
7	Bahiagrass	Pensacola	350	72.08	94.66	20.59	27.05
8	Bermudagrass	Common	100	26.29	46.98	26.29	46.98
9	Bermudagrass	Common	230	49.18	71.48	21.38	31.08
10	Bermudagrass	Common	300	72.08	95.98	24.03	31.99
11	Bermudagrass w/ Vetch	Coastal/Hairy	493	56.25	83.14	11.41	16.86
12	Bermudagrass w/ Rye	Coastal/Explorer	530	90.46	119.74	17.07	22.59
13	Sorghum/Sudan	Funks 78-F	210	77.40	96.66	36.86	46.03
14	Alfalfa	Cimarron	475	119.54	196.93	25.17	41.46
15	Sericia Lezpedeza(2)	Serala	248	21.41	45.25	8.63	18.25
16	Sericia Lezpecleza(2)	AU Lotan	276	21.41	45.25	7.76	16.39
17	Sericia Lezpedeza	AU Lotan	306	21.41	45.25	7.00	14.79
18	Tall Fescue(3)	AU Triumph (0%)	519	90.42	115.67	17.42	22.29
19	Tall Fescue	KY 31 (1°%)	462	90.42	115.67	19.57	25.04
20	Tall Fescue	KY 31 (34%)	397	90.42	114.99	22.78	28.96
21	Tall Fescue	KY 31 (90%)	370	90.42	114.99	24.44	31.08
22	Tall Fescue	KY 31 (<5%)	426	90.42	115.67	21.23	27.15
23	Tall Fescue	KY 31 (94%)	301	90.42	114.99	30.04	38.20
24	Tall Fescue	KY 31 (High%)	268	90.42	114.99	33.74	42.91
25	Orchardgrass	Common	200	75.58	100.25	37.79	50.13
26	Tall Fescue	KY 31 (0%)	434	90.42	115.67	20.83	26.65
27	Hardinggrass	AP-2	347	90.42	116.18	26.06	33.48
28	Tall Fescue	KY 31	374	75.58	99.11	20.21	26.50
29	Orchardgrass w/ Ladino	Hallmark/Regal	505	39.06	61.56	7.73	12.19
30	Tall Fescue w/ Ladino	KY 31/Regal	244	39.06	60.42	16.01	24.76
31	Orchardgrass w/ Ladino	Common/Regal	244	39.06	61.56	16.01	25.23
32	Tall Fescue w/ Ladino	KY 31/Regal	582	39.06	60.42	6.71	10.38
33	Tall Fescue w/ Birdsfoot	KY 31/Fergus	398	57.66	80.32	14.49	20.18
34	Rye, Oats & Crim. Clover	NS	544	93.83	112.58	17.25	20.69
35	Rye & Ryegrass	NS	528	89.66	108.11	16.98	20.48
36	Rye, Ryegrass & Crimson	NS	364	82.75	111.42	25.48	30.61
37	Oats & Crimson Clover	NS	443	87.30	105.59	19.71	23.84

(1) Variable costs include annual maintenance items such as fertilizer mowing, etc.
(2) Total costs include variable items plus fixed costs associated with establishment and ownership of machinery and equipment.
(3) NS = Not Specified.

Table 3. Estimated total cost of gain for stocker steers utilizing various forage types and varieties.

Item No.	Stocking Rate	Purchase Period	Purchase Price(1)	Animal Costs	Other Costs(2)	Total Variable Costs(3)	Total Costs	Cost of Gain (Variable)	Cost of Gain (Total)
	hd./ac.		$/cwt.	$/ac.	$/ac.	$/ac.	$/ac.	$/cwt.	$/cwt.
1	1.40	Mar-Apr	89.09	623.64	112.30	762.23	786.63	55.44	65.20
2	1.70	Mar-Apr	89.09	757.27	136.36	942.82	968.83	54.57	62.22
3	2.60	Mar-Apr	89.09	1158.18	208.56	1438.82	1466.43	58.47	64.22
4	3.50	Mar-Apr	89.09	1559.09	80.75	1957.71	1988.52	64.29	69.26
5	1.20	Mar-Apr	89.09	534.55	96.26	657.09	676.46	55.70	64.51
6	1.80	Mar-Apr	89.09	801.82	144.39	995.38	1016.36	66.75	73.98
7	2.00	Mar-Apr	89.09	890.91	160.43	1123.42	1146.00	66.43	72.88
8	0.70	Mar-Apr	89.09	311.82	56.15	394.26	414.95	82.44	103.13
9	1.40	Mar-Apr	89.09	623.64	112.30	785.12	807.42	70.21	79.90
10	1.80	Mar-Apr	89.09	801.82	144.39	1018.28	1042.18	72.16	80.12
11	2.26	Mar-Apr	89.09	1006.73	181.28	1244.26	1271.15	48.18	53.64
12	2.45	Mar-Apr	89.09	1091.36	196.53	1378.35	1407.63	54.15	59.67
13	2.80	Mar-Apr	88.00	1232.00	224.60	1534.00	1553.26	143.81	152.98
14	1.30	Mar-Apr	89.09	579.09	104.28	802.91	880.30	47.12	63.41
15	1.30	Mar-Apr	89.09	579.09	104.28	704.78	728.62	50.68	60.29
16	1.20	Mar-Apr	89.09	534.55	96.26	652.21	676.05	42.63	51.27
17	1.20	Mar-Apr	89.09	534.55	96.26	652.21	676.05	38.45	46.24
18	1.54	Sep-Oct	88.00	677.60	123.53	891.55	916.80	41.22	46.09
19	1.32	Sep-Oct	88.00	580.80	105.88	777.10	802.35	42.49	47.96
20	1.40	Sep-Oct	88.00	616.00	112.30	818.72	843.29	51.06	57.25
21	1.77	Sep-Oct	88.00	778.80	141.98	1011.20	1035.77	62.81	69.45
22	1.32	Sep-Oct	88.00	580.80	105.88	777.10	802.35	46.08	52.01
23	1.73	Sep-Oct	88.00	761.20	138.77	990.39	1014.96	76.14	84.31
24	2.13	Sep-Oct	88.00	937.20	170.86	1198.48	1223.05	97.49	106.66
25	1.27	Sep-Oct	88.00	558.80	101.87	736.25	760.92	88.73	101.06
26	1.40	Sep-Oct	88.00	616.00	112.30	818.72	843.97	46.71	52.53
27	1.26	Sep-Oct	88.00	554.40	101.07	745.89	771.65	55.18	62.61
28	1.73	Sep-Oct	88.00	774.40	141.18	991.16	1014.69	57.96	64.25
29	1.97	Sep-Oct	88.00	866.80	158.02	1063.88	1086.38	39.03	43.48
30	1.81	Sep-Oct	88.00	796.40	145.19	980.65	1002.01	75.51	84.27
31	1.46	Sep-Oct	88.00	642.40	117.11	798.57	821.07	64.01	73.23
32	1.63	Sep-Oct	88.00	717.20	130.75	887.01	908.37	29.18	32.85
33	1.24	Sep-Oct	88.00	545.60	99.47	702.73	725.39	39.48	45.17
34	2.00	Sep-Oct	88.00	880.00	160.43	1134.26	1153.01	46.74	50.19
35	1.86	Sep-Oct	88.00	818.40	149.20	1057.26	1075.71	45.24	48.73
36	1.31	Sep-Oct	88.00	576.40	105.08	774.23	792.90	54.35	59.48
37	1.38	Sep-Oct	88.00	607.20	110.70	805.20	823.49	44.69	48.82

(1) Purchase price (deflated) reflects medium #1 steers (500#), Alabama, 1981-90 average.
(2) Other costs reflect starter feed, vet. & med., supplemental feed, etc.
(3) Includes pasture costs.

Table 4. Probability of returns for stocker steers utilizing various forage types and varieties(1).

Item No.	Selling Period	Selling Price(2)	Ending Weight	Mean Returns Above Var. Costs	Mean Returns Above Total Costs	Mean Returns over Var. Costs	Mean Returns over Total Costs	Probability of Returns Above Var. Costs/Acre	Probability of Returns Above Total Costs/Acre	Coefficient of Variation Var. Costs Per Acre(3)	Coefficient of Variation Total Costs Per Acre(3)
			#/hd.	$/ac.	$/ac.	$/hd.	$/hd.	%	%		
1	Sep-Oct	79.64	679	-0.86	-25.26	-0.61	-18.04	52.40	41.40	-114.20	-3.88
2	Sep-Oct	79.64	700	4.71	-21.30	2.77	-12.53	52.00	44.40	25.16	-5.57
3	Sep-Oct	79.64	685	-20.21	-47.82	-7.77	-18.39	46.40	40.80	-8.79	-3.72
4	Sep-Oct	79.64	677	-69.25	-100.06	-19.78	-28.59	39.80	33.40	-3.40	-2.36
5	Sep-Oct	79.64	683	-0.93	-20.30	-0.78	-16.92	50.20	40.40	-88.27	-4.06
6	Sep-Oct	79.64	661	-36.59	-57.57	-20.33	-31.98	37.20	31.40	-3.32	-2.11
7	Sep-Oct	79.64	675	-43.33	-65.91	-21.67	-32.96	37.40	31.80	-3.07	-2.02
8	Sep-Oct	82.64	643	-29.68	-50.37	-42.40	-71.96	28.40	17.00	-1.80	-1.06
9	Sep-Oct	79.64	664	-35.00	-58.20	-25.64	-41.57	34.00	26.40	-2.59	-1.60
10	Sep-Oct	79.64	667	-53.72	-77.62	-29.84	-43.12	35.80	27.40	-2.35	-1.63
11	Sep-Oct	79.64	718	45.50	18.61	20.13	8.23	59.40	54.20	3.38	8.27
12	Sep-Oct	79.64	716	17.58	-11.70	7.18	-4.77	53.00	48.40	9.23	-13.87
13	Aug-Sep	82.09	575	-212.33	-231.59	-75.83	-82.71	11.20	9.00	-0.84	-0.77
14	Sep-Oct	76.64	865	59.47	-17.92	45.74	-13.79	68.20	41.80	1.84	-6.10
15	Sep-Oct	79.64	691	11.91	-11.93	9.16	-9.18	55.40	45.80	8.37	-8.36
16	Sep-Oct	79.64	730	36.91	13.07	30.76	10.89	65.40	56.47	2.46	6.94
17	Sep-Oct	76.64	755	54.57	30.73	45.47	25.61	72.80	60.40	1.61	2.87
18	Jun-Jul	75.55	837	83.47	58.22	54.20	37.81	72.80	67.40	1.59	2.28
19	Jun-Jul	75.55	850	71.95	46.70	54.51	35.38	72.40	64.40	1.68	2.58
20	Jun-Jul	75.55	784	18.65	-5.92	13.32	-4.23	53.40	47.20	6.10	-19.22
21	Jun-Jul	78.55	709	-29.48	-54.05	-16.66	-30.54	42.20	34.20	-4.59	-2.50
22	Jun-Jul	75.55	823	46.55	21.30	35.26	16.13	63.40	56.20	2.44	5.33
23	Jun-Jul	78.55	674	-67.08	-91.65	-38.78	-52.98	32.40	24.40	-1.91	-1.40
24	Jun-Jul	81.55	626	-122.51	-147.08	-57.52	-69.05	22.40	17.00	-1.27	-1.06
25	Jun-Jul	78.55	657	-71.71	-96.38	-56.46	-75.89	27.00	19.40	-1.48	-1.10
26	Jun-Jul	75.55	810	42.47	17.22	30.33	12.30	62.80	55.20	2.92	7.20
27	Jun-Jul	75.55	775	1.48	-24.28	1.18	-19.27	52.00	42.20	69.22	-4.23
28	Jun-Jul	78.55	713	-11.43	-34.96	-6.49	-19.86	49.20	41.20	-11.90	-3.89
29	Jul-Aug	76.18	756	91.80	69.30	46.60	35.18	69.80	64.80	1.83	2.42
30	Jul-Aug	82.18	635	-54.02	-75.38	-29.84	-41.65	34.40	29.40	-2.67	-1.92
31	Jul-Aug	79.18	667	-22.60	-45.10	-15.48	-30.89	43.20	36.80	-5.89	-2.95
32	Jul-Aug	76.18	857	179.76	155.28	110.28	95.26	83.60	79.60	1.16	1.42
33	Jul-Aug	76.18	821	79.90	57.24	64.43	46.16	73.20	67.00	1.58	2.21
34	Apr-May	76.18	772	50.48	31.73	25.24	15.86	63.20	59.20	2.82	4.49
35	Apr-May	76.18	784	58.05	39.60	31.21	21.29	64.40	59.80	2.36	3.46
36	Apr-May	76.18	778	8.77	-9.90	6.69	-7.56	56.40	48.20	10.93	-9.68
37	Apr-May	76.18	821	58.67	40.38	42.52	29.26	68.20	64.20	1.79	2.60

(1) Estimates derived through iterative process (500) with "gain/ac." and "purchase/selling prices" as stochastic variables.
(2) Selling price (deflated) reflects medium #1 steers (700#), Alabama, 1981-90 average. Price adjustments were applied to deviations greater than 50 pounds.
(3) Coefficient of Variation = Standard Deviation / Mean.

AN ECONOMIC COMPARISON OF SOLAR AND LP GAS FORAGE DRYING SYSTEM

F.J. Benson, W. Harrison, B.F. Parker, and M.R. Lindley[1]

ABSTRACT:

This paper assesses the potential for hay drying using solar-thermal energy. The evaluation includes technical, environmental, economic, and institutional parameters. In essence the environmental and institutional parameters are favorable to the use of solar energy. Therefore, the analysis is directed at mainly technical and economic aspects of comparing solar and LP energy sources for drying hay. The analysis shows that this specific use of solar-thermal energy is presently economical and technically feasible. The solar thermal energy used to dry hay has only one drawback to it's use, that of providing enough thermal energy per unit of time to readily complete the drying process of the hay, which can be partially overcome by optimizing the collector/hay ratio.

PERSPECTIVE:

The purpose of this research is to determine if the use of solar energy via solar collectors to dry hay is economically feasible. In addition, the solar collector system will be evaluated against an LP gas drying unit of comparable size.

This is an evaluation of applying solar-thermal energy for drying hay in a structure using fans to force solar-thermal heat through hay placed in the structure. This energy source, the solar collector, requires a high initial investment to construct the system, however, it has very low operating cost and relatively low maintenance if well constructed.

Solar-thermal collectors require considerable collection area if appreciable quantities of energy are to be obtained since solar radiation is a low intensity energy source. Solar-thermal systems have an advantage in agricultural applications where stationary energy units can be utilized and a location for collection facilities can usually be arranged. Roofs and walls on farm buildings can be oriented for maximum solar radiation exposure and used as mounting platforms (thus avoiding construction of support frames).

Since solar radiation is available only a part of each day applications which can utilize the energy at the time it is generated are favored. Although thermal energy can be stored for future use, the energy loss in storage and the cost of storage decreases the economic potential for solar-thermal energy. Hay drying can utilize the energy at the time of collection thus avoiding the costs and energy losses of energy storage.

For economic viability, the large capital investment in a solar energy collector requires an extended period of use during each year. Hay dryers can be used from late spring until fall. The collector may be used for supplemental heating of other farm buildings or the house in off season. The primary cost of solar heating is fixed once the investment is made compared to the lower initial cost of an LP gas dryer and higher variable costs, the LP gas.

Solar-thermal energy is environmentally benign except for manufacturing the solar energy system itself and the small electrical energy used for fans for the solar-thermal energy collection. Therefore, solar energy uses are more environmentally desirable than fossil fuels, except for possible visual drawbacks of solar-thermal units themselves. The reduction in the use of fossil fuels by solar energy sources is welcomed by society. There are no obvious institutional barriers to the use of solar energy. Therefore, the use of solar energy as an energy source will mainly depend on the technical and economic parameters since they possess positive environmental and social values.

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TECHNICAL AND ECONOMIC ASSESSMENT:

Alfalfa Drying: The data for alfalfa drying came from a research facility at the University of Kentucky (Parker, et al. 1986 and 1990). The solar heating system cost consisted of the collector and duct cost minus the cost of a metal roof. The research drying unit was a building 9.75m long by 7.6m wide by 5.2m high to the ceiling. The building was divided down the middle and one side was used for the solar system and the other for the LP system. The hay was dried in bins the same size, 3.66m x 3.66 m. The maximum amount of hay that could be dried in a batch in each bin was approximately 6.66 metric tonnes (7.33 US tons) as measured at 18% moisture content. Air flow was supplied to each bin by a 3.7 - 5.2 kw fan with total air flow ranging from 2.05 - 3.43 m^3/s (4344 - 7275 cfm) depending upon the density and depth of the hay.

Comparison of solar investment was then made to the cost of an LP gas burner plus the fuel cost using a ten year life for each. The specific data used in the analysis are presented in Table 1. Operational time for the dryers was taken as 50% of an estimated 158 harvest days to allow time for loading, unloading and harvest schedules.

The economic model used to compare the various energy systems was a present value model which weights the values over time. This model is more typically described as a "Discounted Net Cash Flows Model". The overall costs are provided in Tables 2 and 3 which represent the Solar drying unit and the LP drying unit, respectively. Each system is analyzed over an expected life of 10 years. The total costs shown do not include depreciation. Instead the initial cost of the system is considered at the beginning of its life. Tables 2 and 3 show in present value dollars the costs to establish and maintain each system over its economic life. The solar-thermal system requires high initial investments. The alternatives to these systems, fossil fuels and purchased electricity have associated costs that are spread out over time. For example, an LP dryer will have a smaller initial cost and greater annual operating costs because of the LP gas used. Therefore, the appropriate model to use to economically evaluate these energy systems is a present value analysis over the life of the systems, comparing the results in present value dollars.

The results indicate a discounted net cash flow in terms of today's dollars of $10,614 for the solar unit and $16,563 for the LP unit. This analysis is based upon both systems drying the same quantities of hay. Hay was left in the solar unit from 2 to 4 days. The LP system was not tested for its maximum capacity. Testing at high temperatures would result in increased capacity and heat required per unit of dry hay. This analysis merely used the same thermal energy delivered by the solar unit to determine the equivalent thermal energy required by an 80% efficient LP gas burner. The solar unit provided an average of 1.175 Million BTU's per day, an equivalent of 17.4 gallons of LP in an 80% efficient system.

Figure 1 shows the relationship of the present value of heating cost per tonne with both drying units operated simultaneously and the heating systems fully depreciated in 10 years. The use factor applies to both the solar unit and the LP unit. The LP curve assumes the same quantity of hay dried as the solar unit. The input temperature was kept near a 10° C temperature rise for the LP unit in order to decrease heat loss during approximately the last half of the drying cycle.

The potential quantity of alfalfa which might be forced air dried using solar heat was estimated from the alfalfa produced in the humid east (21.7 x 10^6 tonnes, Lenz, et al., 1989) as 25% of production or 5.4 x 10^6 tonnes. Since the heat energy needed is 391 kWh/tonne (Table 1), the total predicted potential use of solar energy for alfalfa drying is 2.1 x 10^9 kWh/yr.

The matching of energy use in alfalfa drying to the timing of energy collection does not present a problem except the possibility that an extended long cloudy period results in slower drying with some potential for mold growth. Slower drying also results because of the solar heat availability

during daylight hours only. A new system design should use higher air flow and/or temperature than used in the research system to be sure no mold occurs. A solar-heated farmer-operated alfalfa dryer in central Kentucky has not experienced problems with either of these. However, it is recognized that a greater quantity of alfalfa could be dried using LP Gas as compared to this solar heated research unit. A larger solar collector could also increase the capacity. Optimization and further development of solar heat for use in hay drying is needed.

SUMMARY AND CONCLUSIONS:

The data presented show that solar heat is presently more economical and environmentally desirable than the use of LP gas for drying alfalfa hay in the humid eastern part of the U. S.. The present value model used in this analysis the higher weighted costs in present years of the solar unit versus the discounted costs in future years the LP system. However, the higher initial cost system competed successfully against the LP gas alternative. Although the quantities of energy involved are relatively small compared to the massive quantities of energy use in the United States, a significant quantity of fossil fuel could be saved at the present time.

Further development of forced air solar heated hay drying is needed since the system analyzed satisfies all technical, environmental, economic and institutional requirements.

DEFINITIONS:

Interest, Borrowed Capital - The interest rate on borrowed capital reflects the cost to the farmer of borrowing capital in the long term. In this paper the long term refers to the life of the solar collector and is taken to be 10 years. This parameter may vary across individual farms.

Discount Rate - The discount rate is used to calculate the present value of a future stream of expected payments and reflects the opportunity cost of capital. The value used in this paper is based on the present annual rate of return for U.S. treasury bills.

Depreciation Rate - The depreciation rate is used to calculate the yearly depreciation expense. The straight line method is used over a 10 year collector life.

Insurance, Taxes and Repairs - This factor is used to calculate the annual expense associated with insurance, tax, and repair costs over the life of the collector.

Fuel Inflation Factor - This factor is used to adjust the annual fuel costs for anticipated inflation over the life of the collector.

Use Factor - The ratio of days used to the total number of possible days of use.

Capacity Factor - The ratio of energy generated to the energy that would be generated if operated continuously at full capacity.

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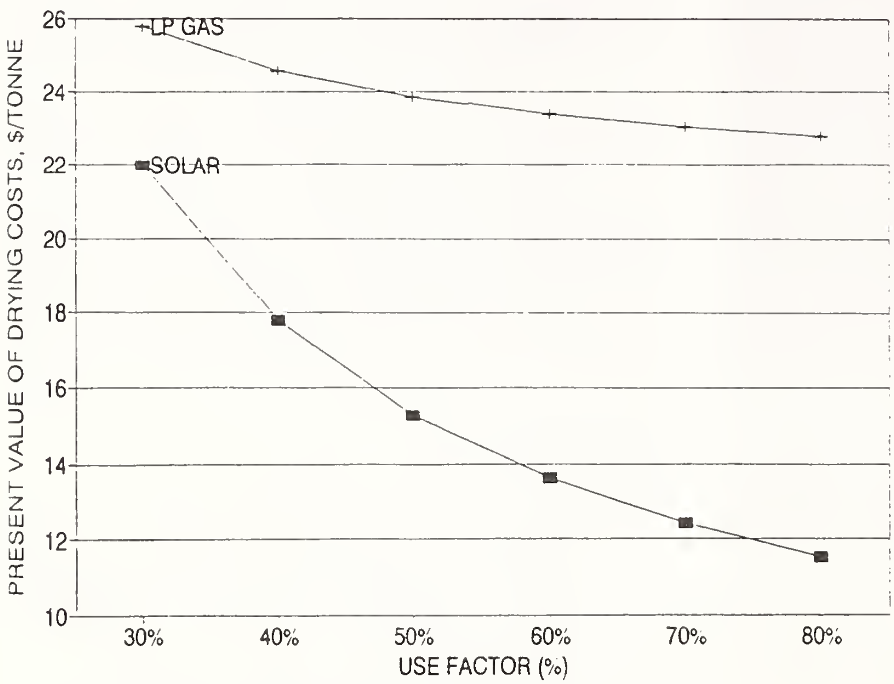

Figure 1. Comparative Drying Costs per Tonne of Alfalfa Hay in Kentucky with LP Gas and Solar as Energy Sources.

TABLE 1	
Parameters Used for Analyses	
Parameter	Value
Size of Collector, sq. meters.	107
Maximum Drying Capacity, tones/yr.	69.5
Use Factor, %.	50
Average Solar Energy Collected, kW-hr/day*	344
Average Solar Energy Collected, kW-hr/yr*. LP Gas Equivalent, liters.	27172 5193
Electricity Use, kW-hr/day. (Solar and LP)	127.2
Heat Energy, kW-hr/tonne.	391
LP Burner Efficiency, %.	80
Economic Parameters	
Cost of Solar Collector, $.	4608
Cost of LP Gas Burner, $.	1322
Interest, Borrowed Capital, %	11
Discount rate, %	7.5
Depreciation Rate, %/yr	10
Insurance, Taxes & Repairs, %/yr.	2
Electricity Cost, ¢/kW-hr.	6
LP Gas Cost, $/liter.	0.26
Fuel Inflation Factor, %/yr. (On LP Gas)	4

*Average solar energy collected is computed for a 50% use factor during a 158 day harvest period.

TABLE 2 The Discounted Net Cash Flows of the Solar Hay Drying Unit									
Year	Value	Depre-ciation	Interest	Insurance and Repairs	Electri-city	Fuel	Total Costs	Present Val Factor	Present Value
0	$4,608						$4,608	100.00%	$4,608
1	$4,147	$461	$456	$92	$547	$0	$1,095	92.50%	$1,013
2	$3,686	$461	$406	$92	$547	$0	$1,045	85.56%	$894
3	$3,226	$461	$355	$92	$547	$0	$994	79.15%	$787
4	$2,765	$461	$304	$92	$547	$0	$943	73.21%	$691
5	$2,304	$461	$253	$92	$547	$0	$893	67.72%	$604
6	$1,843	$461	$203	$92	$547	$0	$842	62.64%	$527
7	$1,382	$461	$152	$92	$547	$0	$791	57.94%	$458
8	$922	$461	$101	$92	$547	$0	$740	53.60%	$397
9	$461	$461	$51	$92	$547	$0	$690	49.58%	$342
10	($0)	$461	($0)	$92	$547	$0	$639	45.86%	$293
TOTALS		$4,608	$2,281	$922	$5469		$13,281		$10,614

TABLE 3 The Discounted Net Cash Flows of the LP Hay Drying Unit									
Year	Value	Depreciation	Interest	Insurance and Repairs	Electricity	Fuel	Total Costs	Present Val Factor	Present Value
0	$1,322						$1,322	100.00%	$1,322
1	$1,190	$132	$131	$26	$547	$1,396	$2,100	92.50%	$1,943
2	$1,058	$132	$116	$26	$547	$1,452	$2,141	85.56%	$1,832
3	$925	$132	$102	$26	$547	$1,510	$2,185	79.15%	$1,729
4	$793	$132	$87	$26	$547	$1,570	$2,231	73.21%	$1,633
5	$661	$132	$73	$26	$547	$1,633	$2,279	67.72%	$1,543
6	$529	$132	$58	$26	$547	$1,698	$2,330	62.64%	$1,459
7	$397	$132	$44	$26	$547	$1,766	$2,383	57.94%	$1,381
8	$264	$132	$29	$26	$547	$1,837	$2,439	53.60%	$1,307
9	$132	$132	$15	$26	$547	$1,910	$2,498	49.58%	$1,239
10	($0)	$132	($0)	$26	$547	$1,987	$2,560	45.86%	$1,174
TOTALS		$1,322	$654	$264	$5,469		$24,469		$16,563

Minutes of executive committee meeting (May 13, 1991); Ken Quesenberry, University of Florida, presiding. The following topics were discussed:

Future conferences - the 48th SPFCIC will be held at Auburn University, Auburn, Alabama on April 20 - 21, 1992. The next Trifolium Conference will be held at Gainesville, Florida on March 26 27, 1992. The host for the 48th SPFCIC is to be reminded that $5.00/person should be added to the registration fee to cover the cost of publishing the proceedings. It was recommended that the second announcement of the meeting should be mailed to participants eight weeks before the meeting, and that the local arrangements chairman for the upcoming meeting should attend the executive committee meeting.

Workgroups - chairman of the individual workgroups were reminded to elect new secretary~ for the upcoming year. Chairman of the workgroups are: Wink Allison (Ecology/Physiology), Ray Smith (Breeding), Sim Reeves (Extension), Dwight Fisher (Utilization). It was noted that the Breeding Workgroup participates in the Southern Regional Information Exchange Group and that it may be important for the other workgroups to participate in the future.

Publication of papers - in order to avoid delay in publishing the proceedings, papers for all future meetings should be given to Roger Gates preferably at the meeting and no later than four weeks after the meeting. Anything submitted after this final deadline will be left out of the proceedings.

Accounts - Wayne Hanna will be the cosigner for the postal account. In anticipation of Geoff Brink taking over the Secretary-Treasurer position from James Green, once bills for the 47th conference are paid, the account will be transferred from Raleigh, NC to Starkville, MS.

Development of a SPFCIC logo - it was decided to offer a motion at the general business meeting to develop a logo for placement on the traveling plaque and gavel. A $100.00 prize will be given to the person submitting the logo chosen. Submissions will be restricted to members.

Respectively submitted,

Geoffrey E. Brink Secretary-Treasurer elect

47th Annual Southern Pasture and Forage Crop Improvement Conference

Minutes of the business meeting - Forage Breeder's Work Group
May 14, 1991

The business meeting was called to order by Ray Smith, Chairman. Gary Pederson nominated David Wofford to be the incoming secretary. Ken Quesenberry moved that nominations be closed and election was unanimous.

E.R. Emino, advisor to the Southern Regional Information Exchange Group, gave a report as did Preston Jones, CSRS representative, who announced that a Forage Research Evaluation Workshop to identify major national research needs will be held in the summer of 1992 and also, that a workshop to develop a new Forage Quality Handbook will be held in 1994 in Lincoln, NB.

Joe Bouton announced that the North American Alfalfa Improvement Conference will be held in Atlanta, GA in 1992, and Ken Quesenberry announced that the 12th Trifolium Conference will be held in March, 1992 in Gainesville, FL.

The meeting was then adjourned by Ray Smith.

Submitted by Bruce A. Young, Secretary

MINUTES OF THE 47TH SPFCIC FORAGE UTILIZATION WORK GROUP BUSINESS MEETING

Mississippi State University
Starkville, MS
May 14, 1991

The business session was called to order by F. T. Withers, Secretary, in absence of Dwight S. Fisher, Chairman and Monte Rouquette, Chairman-Elect at Mississippi State University on May 14, 1991. A record of those attending the Utilization Work Group session was recorded.

A motion was made and seconded to dispense with the reading of the minutes of the 46th SPFCIC meeting held in Kilgore, Texas.

membership, regarding topics of interest for future meetings and for them to be conveyed to Monte Rouquette.

Old business discussion included an explanation for the delay in the publishing of the 46th SPFCIC Proceedings, which occurred due to lateness in submission of papers.

New business matters included the announcement that the SPFCIC meetings for 1992, 1993, and 1994 would be hosted in the states of Alabama, Florida and Tennessee, respectively. The Utilization Group received an invitation from the Alabama group for the 48th meeting of SPFCIC, to be held on April 2022, 1992 at Auburn, Alabama.

A resolution passed by the Executive Board of the SPFCIC was conveyed to the membership, stating that to expedite the publishing of all future proceedings, a deadline of July 1 has been implemented and all publishable material received after this date will be omitted. All material for the 47th Proceedings are to be submitted to Roger Gates at the Coastal Plain Experiment Station, Tifton, Georgia.

RESOLUTION

WHEREAS, the membership of the 47th Annual Southern Pasture and Forage Crop Improvement Conference has gleaned much information and great benefits from its participation in the conference, and

WHEREAS, much information and benefits could not have been realized without the friendly, hospitable and concerted efforts of the staff and administration of the Division of Agriculture, Forestry, and Veterinary Medicine, Mississippi State University.

BE IT RESOLVED that the 47th Conference expresses its grateful appreciation to the staff, faculty, and administration of Mississippi State University for the gracious hospitality, imaginative programming, and well planned and executed tour, which was of interest to the membership, and

THAT special recognition be extended to Dr. R. R. Foil, Vice-President, Division of Agriculture, Forestry, and Veterinary Medicine, Dr. H. D. Palmertree, Director of the Cooperative Extension Service, Dr. V. G. Hurt, Director of the Experiment Station, Dr. W. R. Fox, Dean of the College of Agriculture and Home Economics, the following individuals who served on the local arrangements committee: Drs. Pat Bagley, Geoff Brink, Lamar Kimbrough, David Lang, E. G. Morrison, Vance Watson, Butch Withers, Werner Essig, Chairman.

TO Conference Chairman, Dr. Ken Quesenberry, Immediate Past Chairman (and Program Chairman) Dr. Rob Kalmbacher, Secretary-Treasurer Dr. Jim Green.

TO Session Chairman Ray Smith, Chuck West, Butch Withers, and Lamar Kimbrough.

TO all who presented conference papers.

ADDITIONAL RECOGNITION is given to the following firms who contributed financially to the conference:

Delta and Pine Land Company
Delta Purchasing Federation
ICI Americas, Inc.
Liphatec
Mississippi Cattleman's Association
Mississippi Chemical Corporation
Mississippi Farm Bureau Federation
Mississippi Serum Distributors
Sandoz Crop Protection Corporation
SF Services, Inc.
The Wax Company, Inc.
M. S. D. Agvet

The Resolutions Committee:

Carrol Chambliss
Jorge Mosjidis, Chairman

The Nomination Committee report was presented by Committee Chairman, John Stuedemann. The Committee nominated Sam Coleman, USDA-ARS, El Reno, Oklahoma as Secretary-Elect. A motion was made and seconded for his election by acclamation. The 1991-92 slate of officers for the Utilization Work Group are Monte Rouquette, Chairman, F. T. Withers, Chairman-Elect, and Sam Coleman, Secretary-Elect.

With no further new business pending, the meeting was adjourned by motion.

Minutes of Extension Work Group 47TH Annual SPFCIC

Of the 13 Southern States 8 had members attending and 4 states were absent. Attending were Tennessee, North Carolina, Alabama, Florida, Kentucky, Oklahoma, Mississippi and Louisiana. States not attending were Georgia, South Carolina, Virginia, Texas and Arkansas.

The informal program consisted of individual reports from each participating state. The reports included the forage programs for these states to include new varieties, products, practices and updates of extension programs.

Members reporting were: Joe Burns - Tennessee; Jim Green - North Carolina; Don Ball - Alabama; Carrol Chambliss - Florida; Monroe Rasnake - Kentucky; Loren Rommann - Oklahoma; Lamar Kimbrough - Mississippi and Wade Faw - Louisiana.

Others attending were Warren Thompson from Agripro Biosciences Inc. (ABI) and Foy Campbell Delta and Pine Land Company. Each joined our discussions and Warren gave an update report on Alfagraze alfalfa.

These minutes were taken by Lamar Kimbrough - Mississippi.

SOUTHERN PASTURE AND FORAGE CROP IMPROVEMENT CONFERENCE EXECUTIVE COMMITTEE 1992

Executive Officers

John Stuedemann	Chairman
Chuck Dougherty	Chairman-elect
Jim Green	Chair-elect-elect
Ken Quesenberry	Immediate Past Chairman and Program Chairman for 1992 (48th Meeting)
Geoff Brink	Secretary-Treasurer
Bruce Young	Breeders Work Group Chairman
David Lang	Ecology-Physiology Work Group Chairman
Monte Rouquette	Utilization Work Group Chairman
Lamar Kimbrough	Extension Work Group Chairman
Roger Gates	ARS Coordinator

Breeders Work Group

Bruce Young	Chairman
David Wofford	Secretary
Ray Smith	Past Chairman and Program Director

Ecology-Physiology Work Group

David Lang	Chairman
Matt Sanderson	Secretary
Wink Allison	Past Chairman and Program Director

Utilization Work Group

Monte Rouquette	Chairman
Butch Withers	Chairman-elect
Sam Coleman	Secretary
Dwight Fisher	Past Chairman

Extension Work Group

Lamar Kimbrough	Chairman and Program Director
Don Ball	Secretary
Sim Reeves	Past Chairman

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